

Introduction to the Semantic Web

Questions

- What is the Semantic Web?
- Why do we want it?
- How will we do it?
- Who will do it?
- When will it be done?

“XML is Lisp's bastard nephew, with uglier syntax and no semantics. Yet XML is poised to enable the creation of a Web of data that dwarfs anything since the Library at Alexandria.”

-- Philip Wadler, *Et tu XML? The fall of the relational empire*, VLDB, Rome, September 2001.

“The web has made people smarter.
We need to understand how to use it
to make machines smarter, too.”

-- Michael I. Jordan, paraphrased
from a talk at AAAI, July 2002
by Michael Jordan (UC Berkeley)

“The Semantic Web will globalize knowledge representation, just as the WWW globalized hypertext”

-- Tim Berners-Lee

Web is our greatest knowledge source



But it has limitations



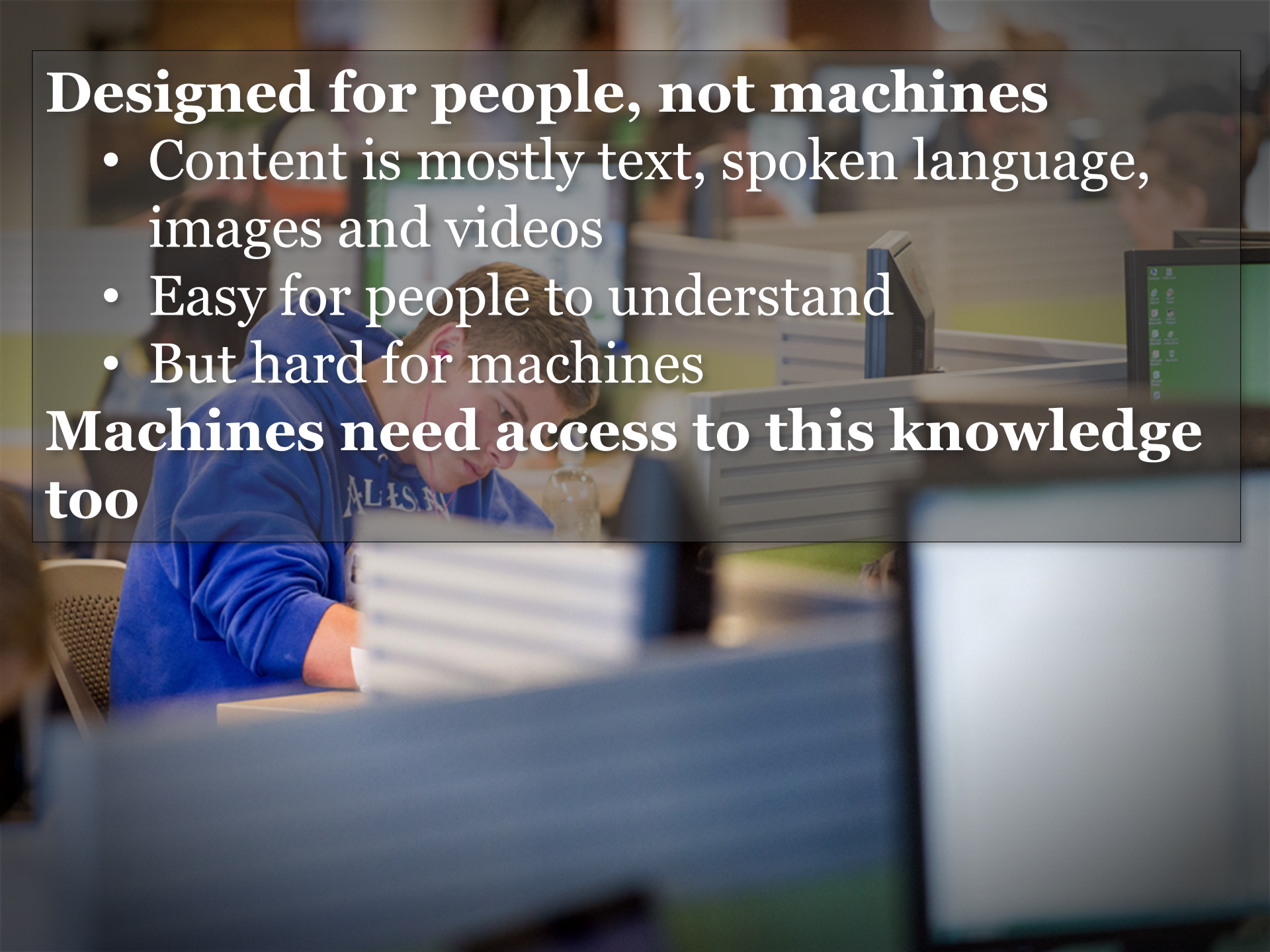
Designed for people, not machines



Designed for people, not machines

- Content is mostly text, spoken language, images and videos
- Easy for people to understand
- But hard for machines

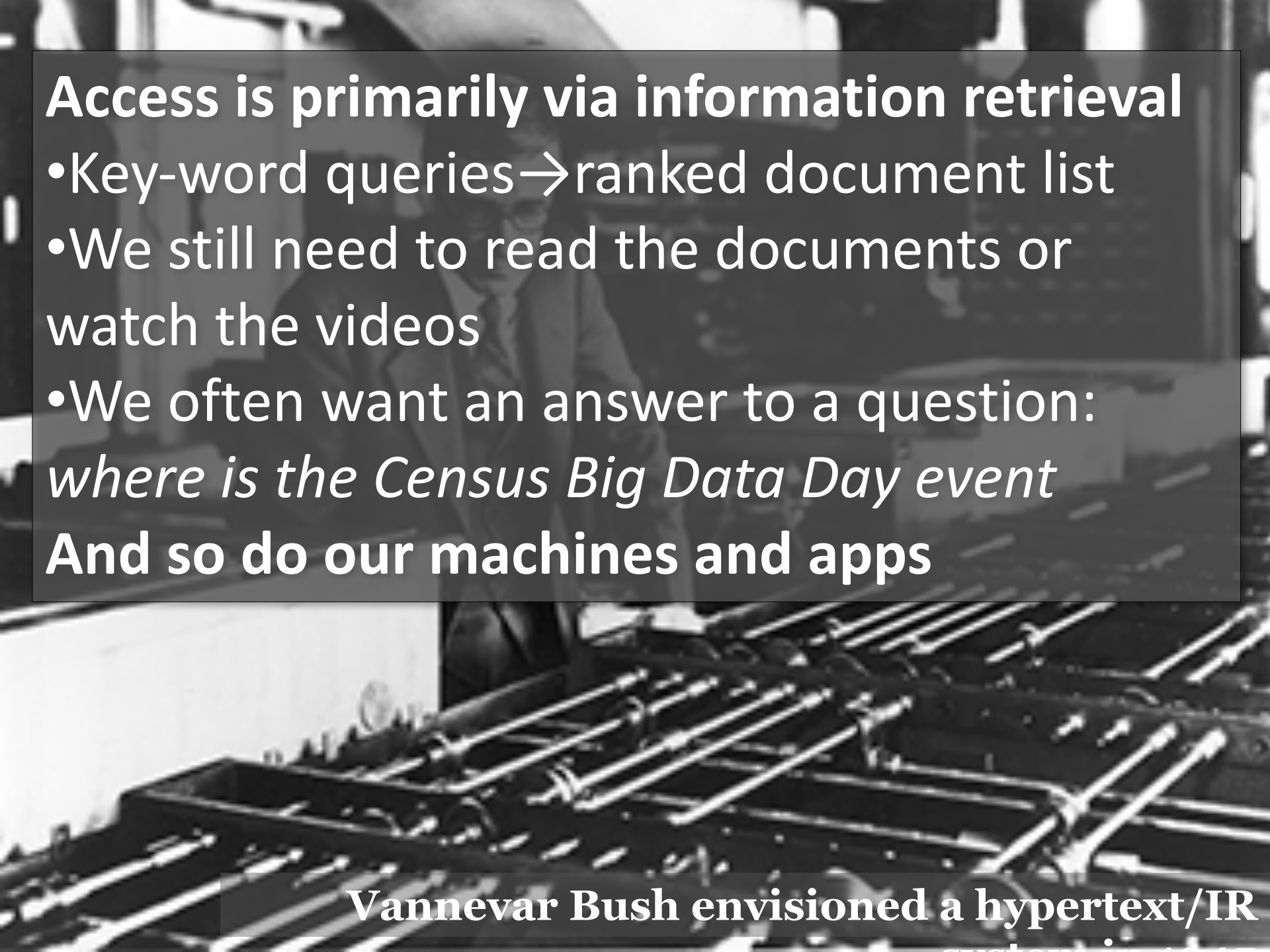
Machines need access to this knowledge too



Access via information retrieval



Vannevar Bush envisioned a hypertext/IR system in 1945

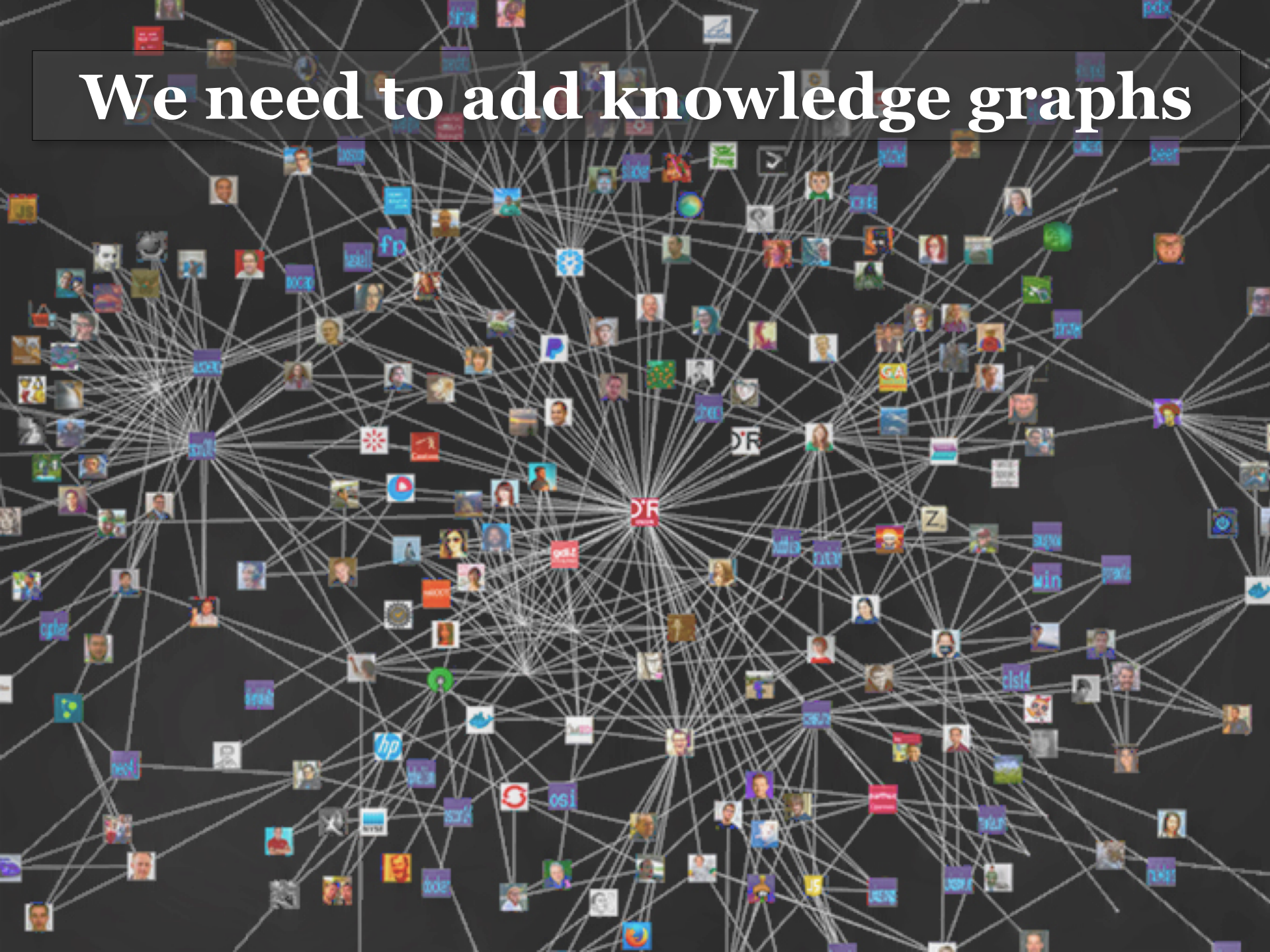


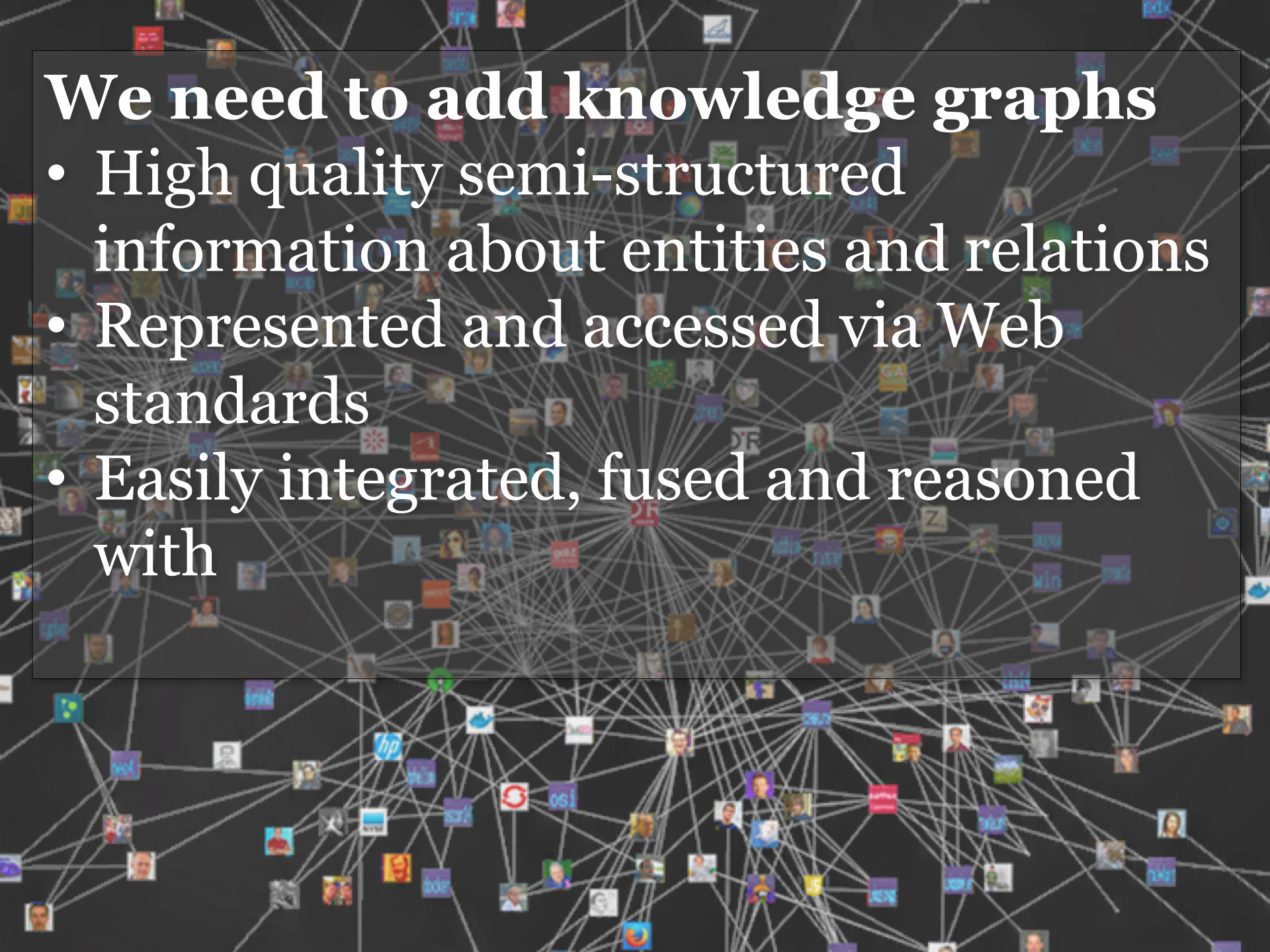
Access is primarily via information retrieval

- Key-word queries → ranked document list
- We still need to read the documents or watch the videos
- We often want an answer to a question:
where is the Census Big Data Day event
And so do our machines and apps

Vannevar Bush envisioned a hypertext/IR

We need to add knowledge graphs



The background of the slide is a dense, complex network graph. It consists of hundreds of small, colorful nodes (squares and circles) connected by a web of thin, light-gray lines. The nodes contain various images, including logos (like HP, Intel, and others), small portraits of people, and abstract symbols. The overall effect is a highly interconnected, chaotic-looking web of information. A semi-transparent dark gray rectangular box is positioned in the upper-left quadrant, containing the main text and bullet points.

We need to add knowledge graphs

- High quality semi-structured information about entities and relations
- Represented and accessed via Web standards
- Easily integrated, fused and reasoned with



State of the Art?

Google is a good example, but Microsoft, IBM, Apple and Facebook all have similar capabilities

- 2010 Google acquired MediaWeb and its **Freebase** KB
- 2014: Freebase: 1.2B facts about 43M entities
- 2015+: Google knowledge graph, updated by text IE

DBpedia open source RDF KB is another

- 800M facts about 4.6M subjects from English **Wikipedia**, data also available in 21 other languages
- Helps integrate 90B facts from 1000 RDF datasets in the linked data cloud

Ask: When was Tom Sawyer written?

when was tom sawyer written

Google

when was tom sawyer written

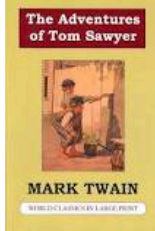
Sign in

All Images Videos News Shopping More Settings Tools

About 501,000 results (0.56 seconds)

The Adventures of Tom Sawyer / Date written

1876



The Adventures of Tom Sawyer
MARK TWAIN

Aunt Polly (aunt), Sally Phelps (aunt), Mary (cousin), Sid (half-brother)
Thomas "Tom" Sawyer is the title character of the Mark Twain novel The Adventures of Tom Sawyer (1876). He appears in three other novels by Twain: Adventures of Huckleberry Finn (1884), Tom Sawyer Abroad (1894), and Tom Sawyer, Detective (1896).

[Tom Sawyer - Wikipedia](https://en.wikipedia.org/wiki/Tom_Sawyer)
https://en.wikipedia.org/wiki/Tom_Sawyer

Feedback

People also ask

Where was The Adventures of Tom Sawyer first published?

How old is Tom Sawyer in the book?

What is the setting for The Adventures of Tom Sawyer?

Who is Tom Sawyer in real life?

The Adventures of Tom Sawyer

Novel by Mark Twain

Preview book

Originally published: 1876
Author: [Mark Twain](#)
Text: The Adventures of Tom Sawyer at Wikisource
Cover artist: Created by Mark Twain
Characters: [Tom Sawyer](#), [Huckleberry Finn](#), [Becky Thatcher](#), [Aunt Polly](#), [Joe Harper](#), [Sid Sawyer](#)
Genres: Bildungsroman, Picaresque Fiction, Satire, Folklore, Children's literature
Followed by: [Wuthering Heights](#), [The Prince and the Pauper](#)

Feedback

Apple Pie by Grandma Ople

★★★★★

9K made it | 6969 reviews

 26

Recipe by: MOSHASMAMA

"This was my grandmother's apple pie recipe. I have never seen another one quite like it. It will always be my favorite and has won me several first place prizes in local competitions. I hope it becomes one of your favorites as well!"



Featured in Allrecipes Magazine

Save

I Made It

Rate it

Share

Print

Ingredients

1 h 30 m ⌚ 8 servings 🍽️ 512 cals 📊

+

1 recipe pastry for a 9 inch double crust pie

+

1/2 cup white sugar

+

1/2 cup unsalted butter

Domino Pure Cane Granulated Sugar



On Sale

On

⚙️

What's on sale near you.

>

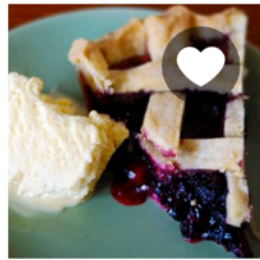


Grandma Ople's Apple Pie

★★★★★ 1930

Related

Recipes Videos Categories Articles



Blueberry Pie

★★★★★ 1K



All-Day Apple Butter

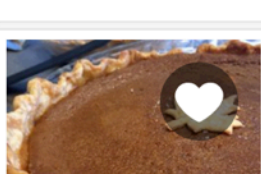
★★★★★ 883

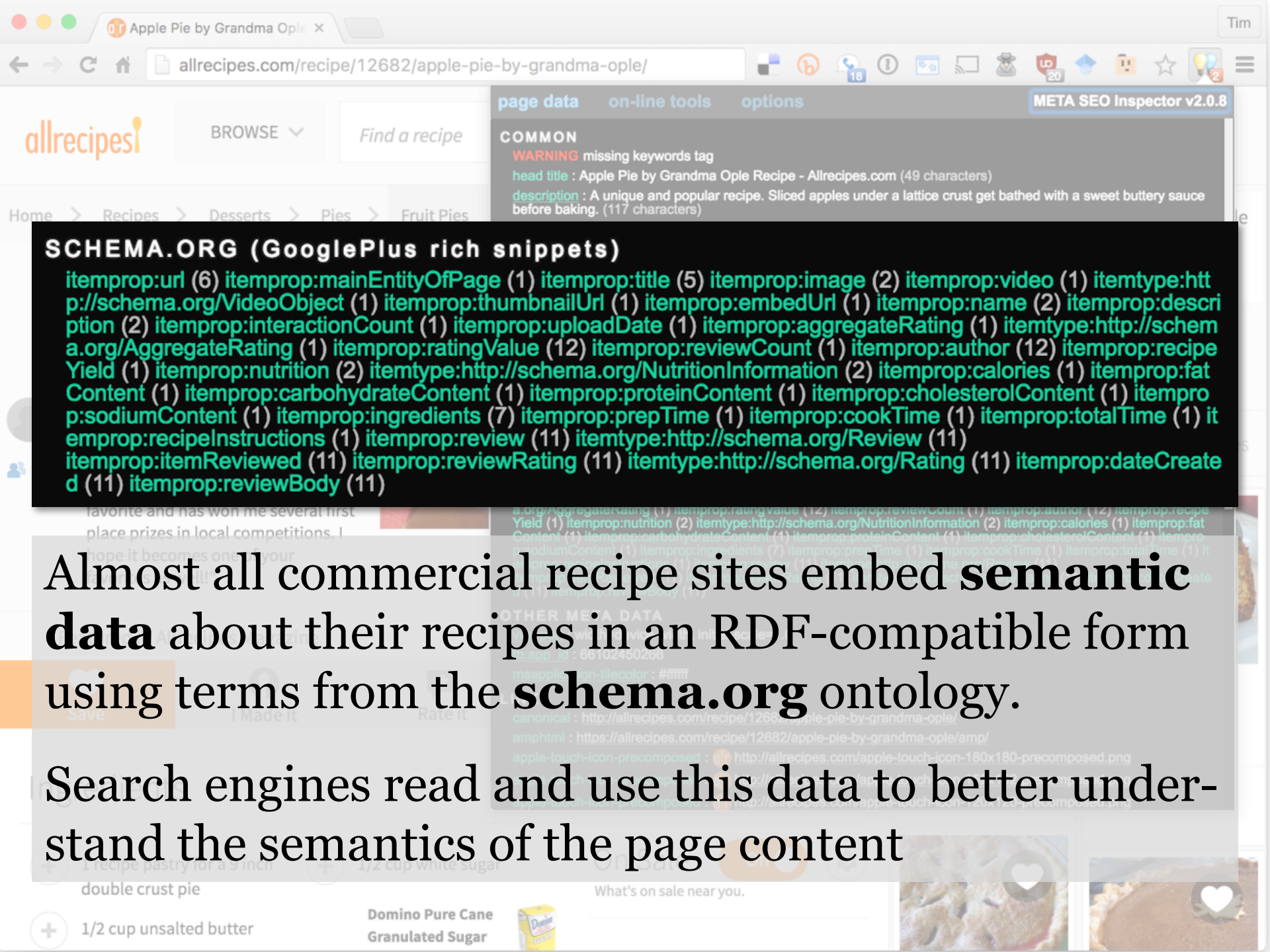
Recipe by ASHESP

👤 3 ❤️ 0 🔔 1



Recipe by Terri





SCHEMA.ORG (GooglePlus rich snippets)

itemprop:url (6) itemprop:mainEntityOfPage (1) itemprop:title (5) itemprop:image (2) itemprop:video (1) itemtype:http://schema.org/VideoObject (1) itemprop:thumbnailUrl (1) itemprop:embedUrl (1) itemprop:name (2) itemprop:description (2) itemprop:interactionCount (1) itemprop:uploadDate (1) itemprop:aggregateRating (1) itemtype:http://schema.org/AggregateRating (1) itemprop:ratingValue (12) itemprop:reviewCount (1) itemprop:author (12) itemprop:recipeYield (1) itemprop:nutrition (2) itemtype:http://schema.org/NutritionInformation (2) itemprop:calories (1) itemprop:fatContent (1) itemprop:carbohydrateContent (1) itemprop:proteinContent (1) itemprop:cholesterolContent (1) itemprop:sodiumContent (1) itemprop:ingredients (7) itemprop:prepTime (1) itemprop:cookTime (1) itemprop:totalTime (1) itemprop:recipeInstructions (1) itemprop:review (11) itemtype:http://schema.org/Review (11) itemprop:itemReviewed (11) itemprop:reviewRating (11) itemtype:http://schema.org/Rating (11) itemprop:dateCreated (11) itemprop:reviewBody (11)

Almost all commercial recipe sites embed **semantic data** about their recipes in an RDF-compatible form using terms from the **schema.org** ontology.

Search engines read and use this data to better understand the semantics of the page content

Conversational Bots

Voice-driven conversational systems like Amazon Echo and Google Home use knowledge graphs to help understand our requests



Where does the knowledge come from?

- Initial knowledge graphs like *DBpedia* and *Freebase* started with data from **Wikipedia** and encoded it in custom ontologies
- Semantic Web technologies are an open source way to encode the knowledge
- They are and will continue to evolve
- A current focus is on extracting information from text of source documents, e.g., journal articles, Newswire, social media, etc.

Why Web Based?

- The web is like a universal acid, eating through and consuming everything it touches.
 - Web principles and technologies are equally good for wireless/pervasive computing
- The semantic web is our first serious attempt to provide semantics for XML sublanguages
- It will provide mechanisms for people and machines (agents, programs, web services) to come together.
 - In all kinds of networked environments: wired, wireless, ad hoc, wearable, etc.

Who invented the Web?

Who invented the Web?



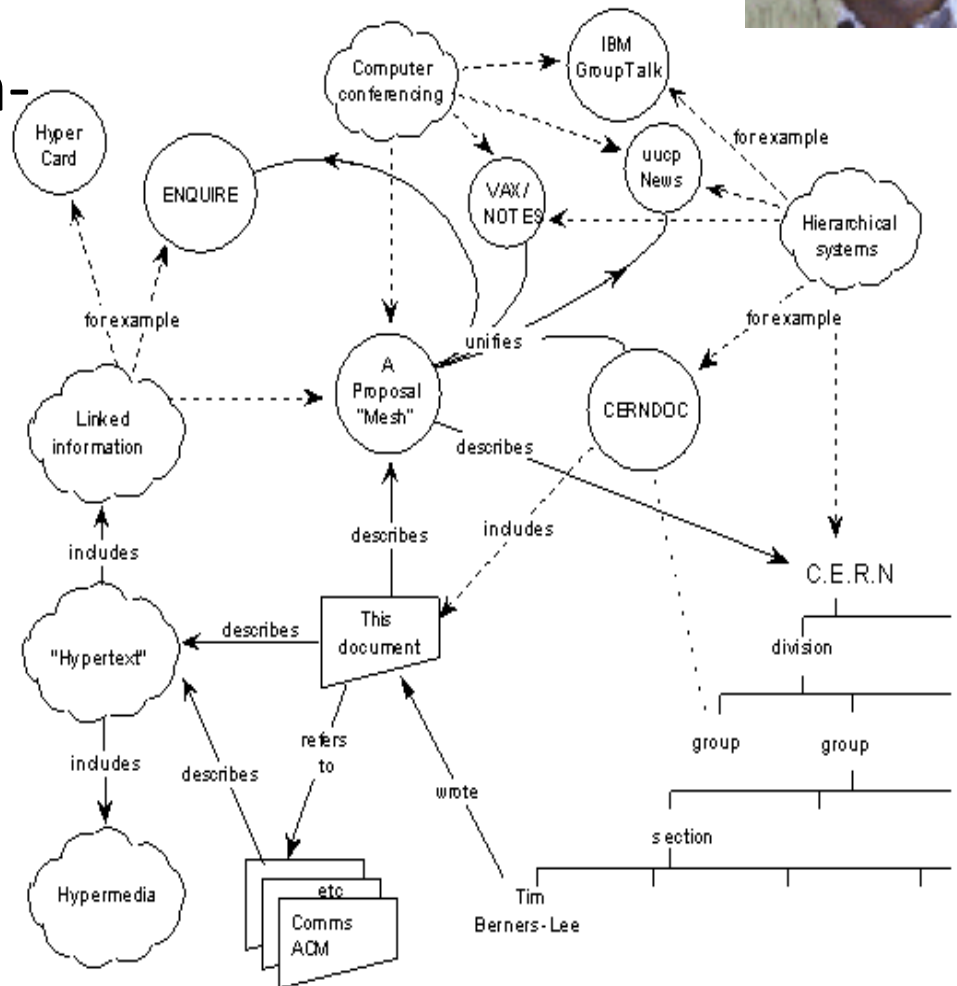
Origins



Tim Berners-Lee's original 1989 WWW proposal described a web of relationships among named objects unifying many info. management tasks.

Capsule history

- Guha's MCF (~94)
- XML+MCF=>RDF (~96)
- RDF+OO=>RDFS (~99)
- RDFS+KR=>DAML+OIL (00)
- W3C's SW activity (01)
- W3C's OWL (03)



<http://www.w3.org/History/1989/proposal.html>

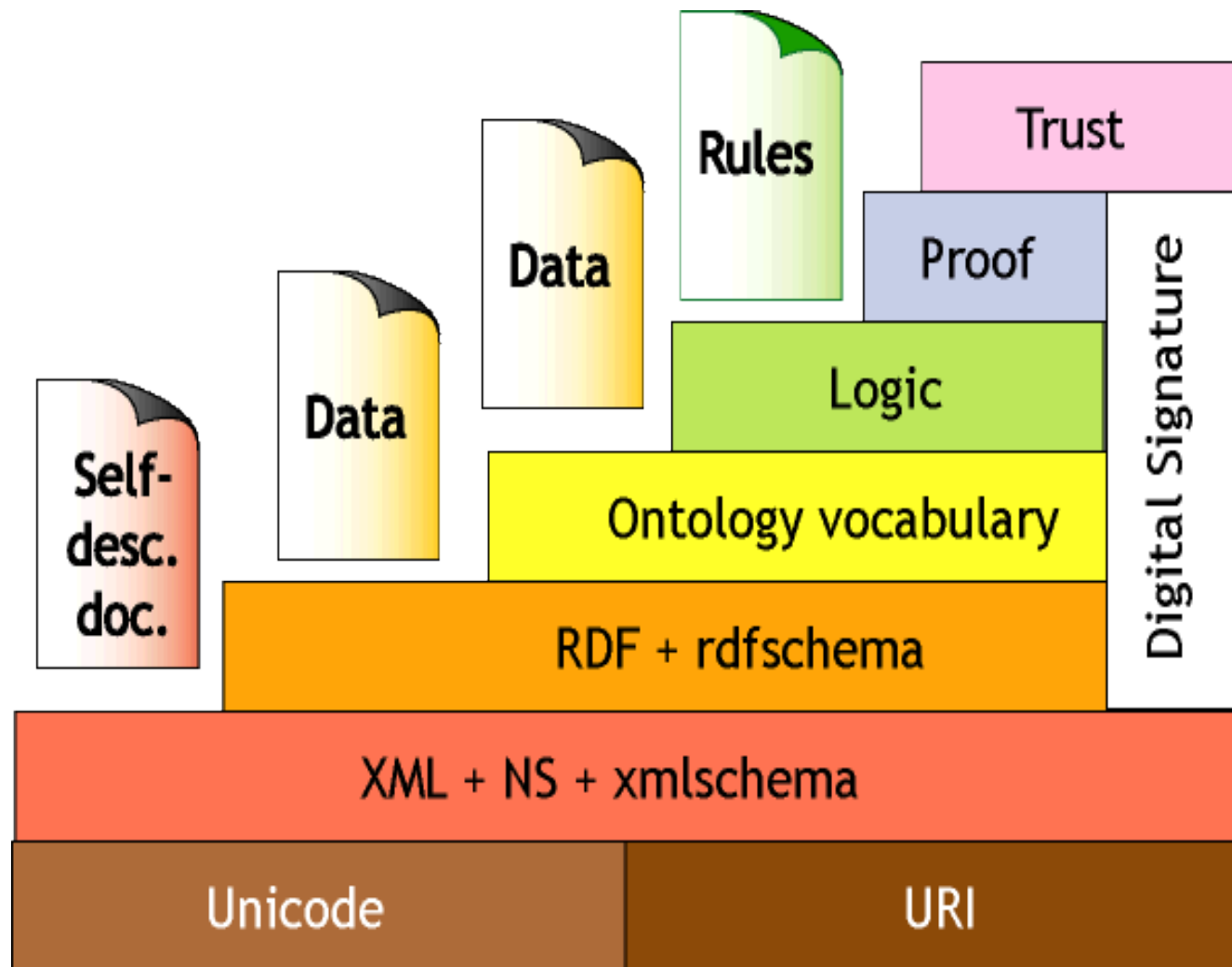
W3C's Semantic Web Goals

Focus on machine consumption:

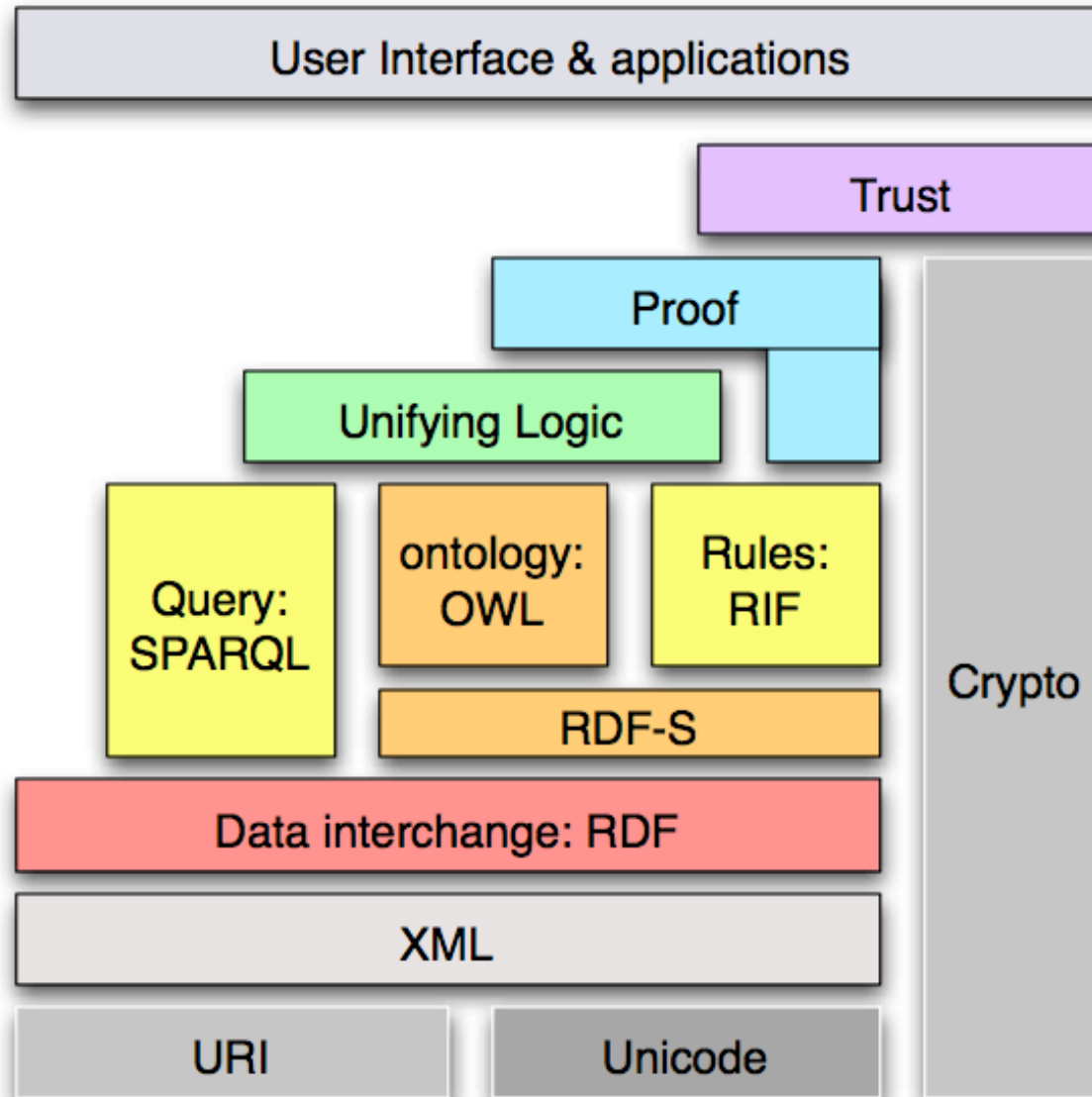
"The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation."

-- Berners-Lee, Hendler and Lassila, The Semantic Web, Scientific American, 2001

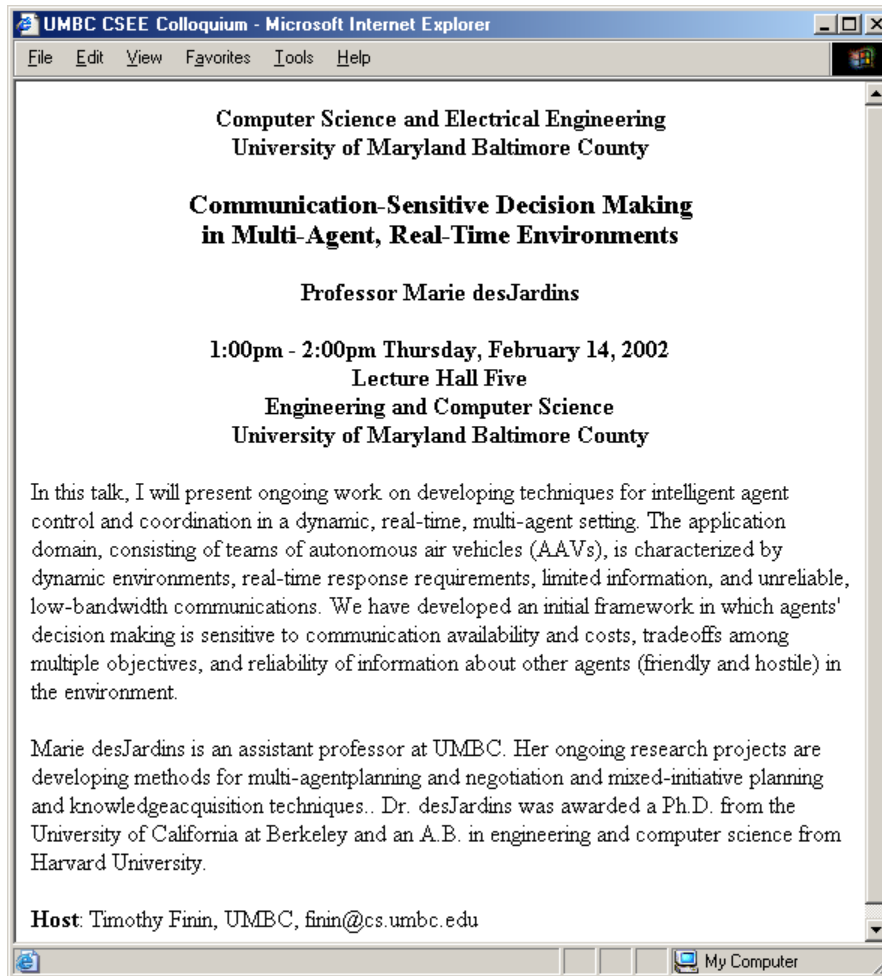
TBL's semantic web vision, circa 2000



Semantic web stack 2006

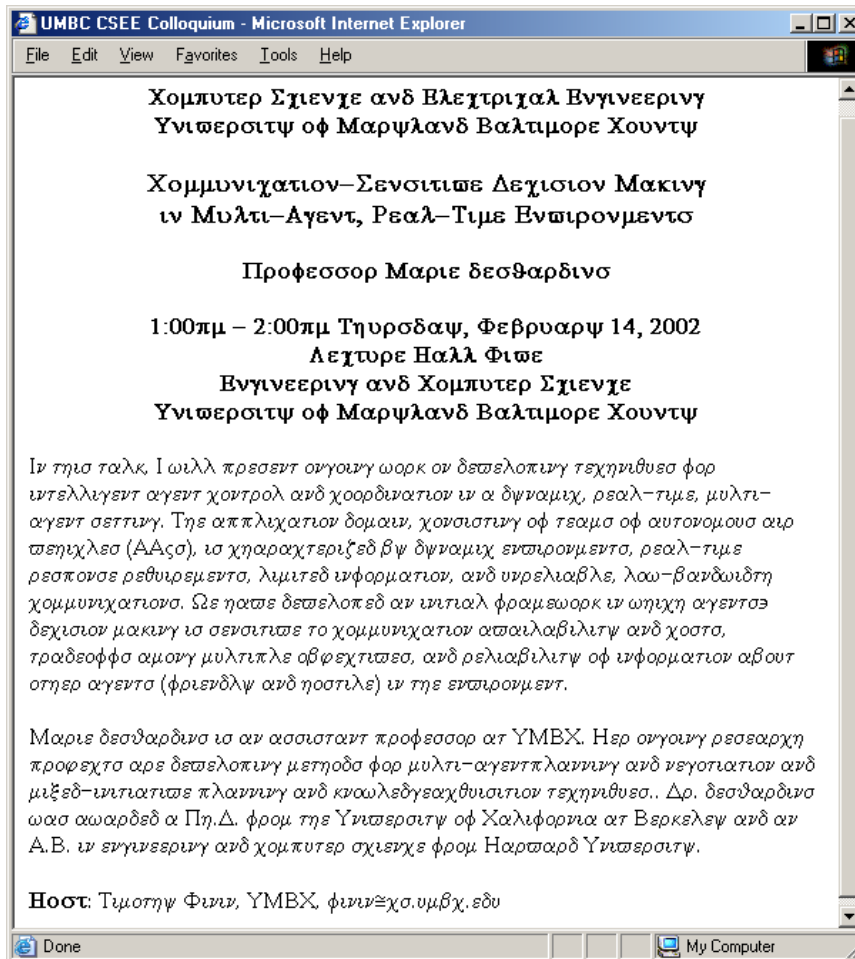


Why is this hard?



after Frank van Harmelen
and Jim Hendler

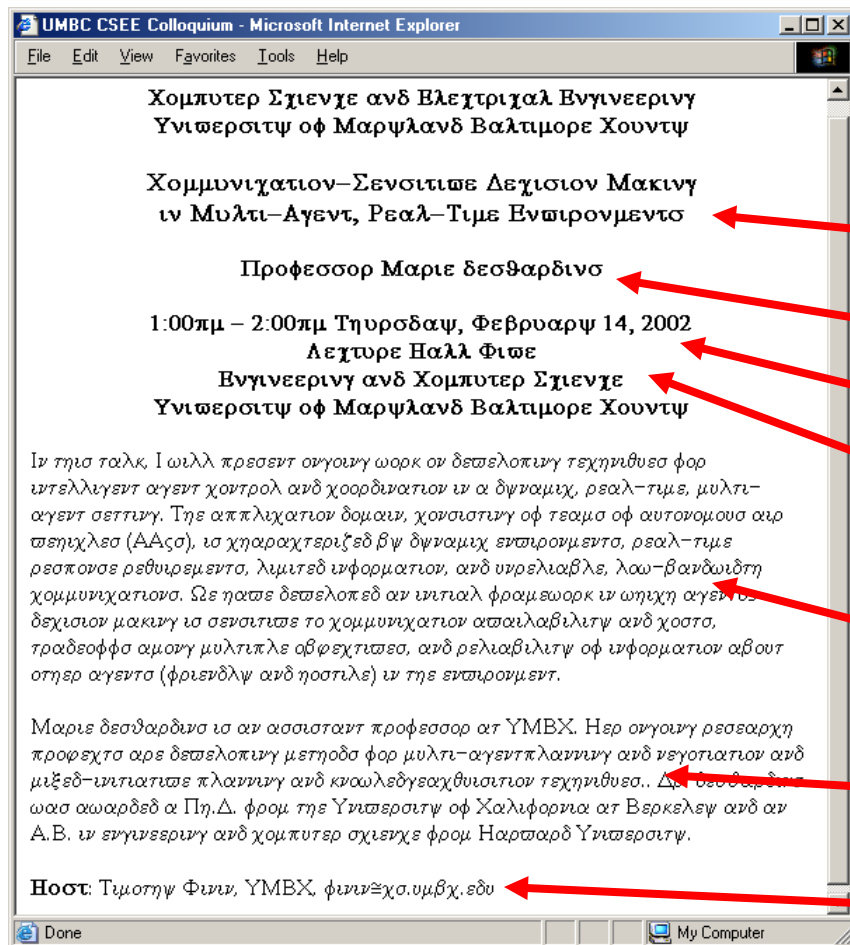
What a web page looks like to a machine...



after Frank van Harmelen
and Jim Hendler

OK, so HTML is not helpful

Maybe we can tell the machine what the different parts of the text represent?



title

speaker

time

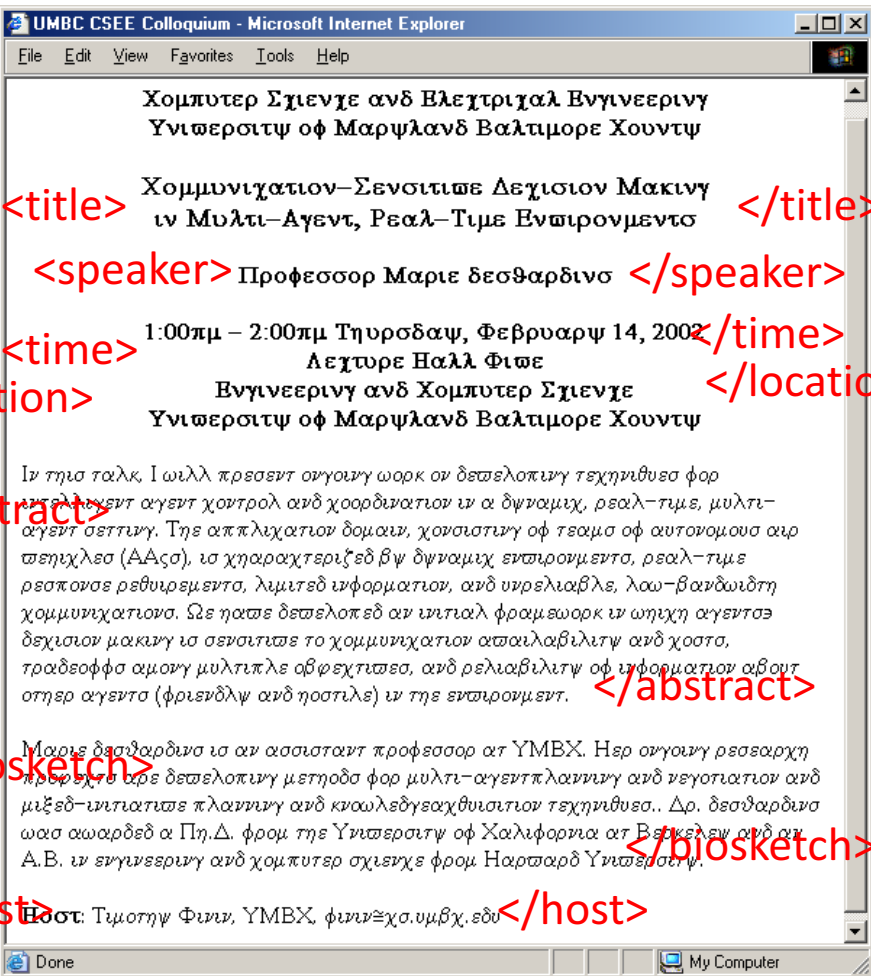
location

abstract

biosketch

host

XML to the rescue?



The screenshot shows a Microsoft Internet Explorer window titled "UMBC CSEE Colloquium - Microsoft Internet Explorer". The address bar is empty. The main content area displays Greek text. Overlaid on the text are several XML tags in red, indicating a markup language being applied to the document. The tags are: <title>, </title>, <speaker>, </speaker>, <time>, </time>, <location>, </location>, <abstract>, </abstract>, <biosketch>, </biosketch>, and <host>, </host>.

Χομπυτερ Σχιενχε ανδ Βλεχτριχαλ Βνγινεερινγ
Υνιφερσιτω οφ Μαρψλανδ Βαλτιμορε Χουντψ

<title> Χομμυνιχατιον-Σενσιτιβε Δεχισιον Μακινγ </title>
ιν Μυλτι-Αγεντ, Ρεαλ-Τιμε Ενπιρονμεντο

<speaker> Προφεσσορ Μαριε δεσθαριντο </speaker>

<time> 1:00πμ - 2:00πμ Τηυρσδαψ, Φεβρουαρη 14, 2002 </time>
Λεχτυρε Χαλλ Φιβε

<location> Βνγινεερινγ ανδ Χομπυτερ Σχιενχε </location>
Υνιφερσιτω οφ Μαρψλανδ Βαλτιμορε Χουντψ

<abstract> Ιν τηισ ταλκ, Ι ωιλλ πρεσεντ ονγοινγ ωορκ ον δεσπελοπιγγ τεχηνηθισ φορ
ιντελλιγεντ αγεντ χοντρολ ανδ χοορδινατιον ιν α δηναμιχ, ρεαλ-τιμε, μυλτι-
αγεντ σεττιγγ. Τηε αππλιχατιον δομαιν, χορσιστιγγ οφ τεαμο οφ αυτονομοουσ αιρ
σπειχλες (ΑΔς), ισ χηαραχτεριζεδ βψ δηναμιχ ενπιρονμεντο, ρεαλ-τιμε
ρεσποנסε ρεθυριεμεντο, λιμιτεδ ινφορματιον, ανδ υνρελιαβλε, λαω-βανδωιδη
χομμυνιχατιον. Ωε ηαπε δεσπελοπεδ αν ιντιαλ φραμewορκ ιν ωηχη αγεντοε
δεχισιον μακινγ ισ σενσιτιβε το χομμυνιχατιον απωιλιαβιλιτω ανδ χοστο,
τραδεοφφσ αμονγ μυλτιπλεσ οβφεχτιβεσ, ανδ ρελιαβιλιτω οφ ινφορματιον αβουτ
οτηερ αγεντο (φριενδλψ ανδ ηοστιλε) ιν τηε ενπιρονμεντο. </abstract>

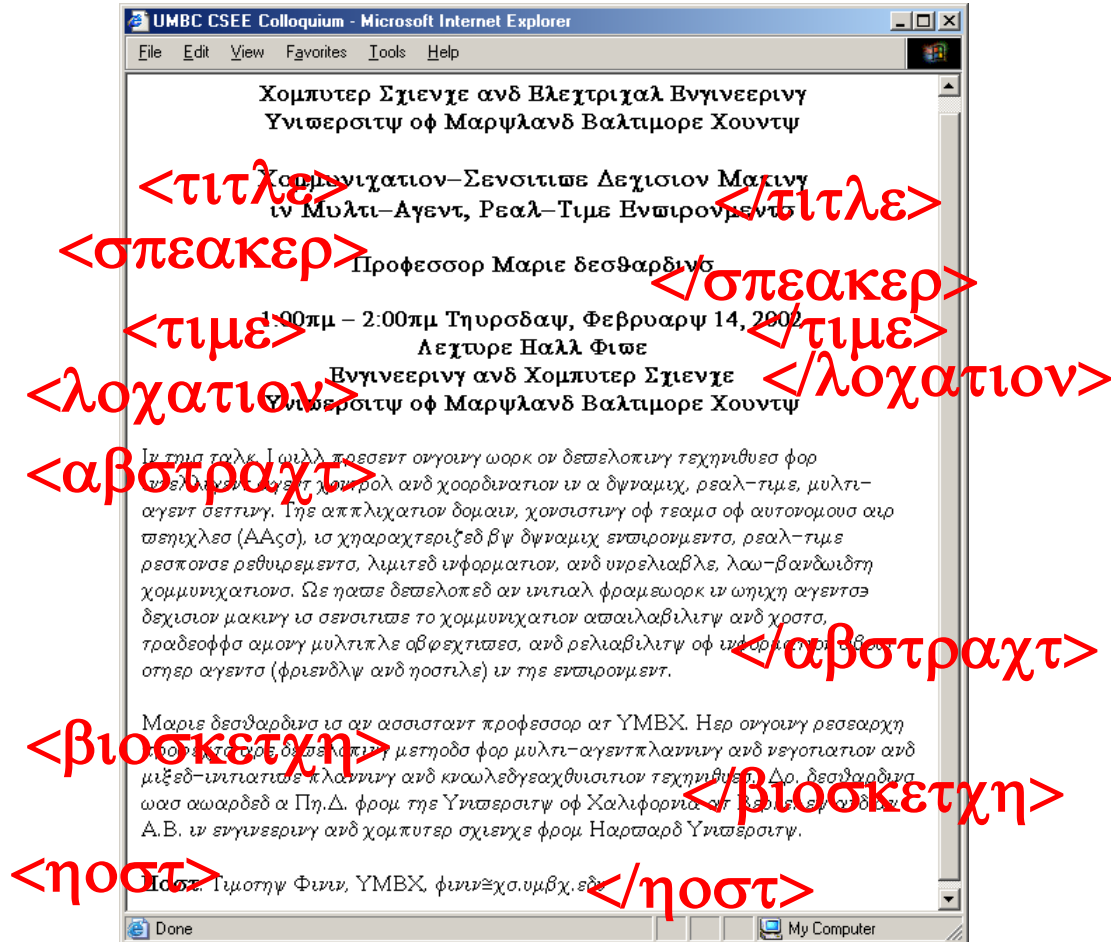
<biosketch> Μαριε δεσθαριντο ισ αν ασισταντ προφεσσορ ατ ΥΜΒΧ. Ηερ ονγοινγ ρεσεαρχη
προφχετα απε δεσπελοπιγγ μεθεδοσ φορ μυλτι-αγεντοπλανιγγ ανδ νεγοτιατιον ανδ
μιξεδ-ιντιατιβε πλανιγγ ανδ κνωλεδγεαχθυσιστιον τεχηνηθισ.. Δρ. δεσθαριντο
ωασ αωαρδεδ ατ Πη.Δ. φορμ τηε Υνιφερσιτω οφ Χαλιφορνια ατ Βερκελεν ανδ αν
Α.Β. ιν ενγινεερινγ ανδ χομπυτερ σχιενχε φορμ Χαρτωαρδ Υνιφερσιτω. </biosketch>

<host> Ηοστ: Τιμοτηψ Φινν, ΥΜΒΧ, φινηχσ.υμβχ.εδν </host>

XML fans propose
creating a XML tag set to
use for each application.

For talks, we can choose
<title>, <speaker>, etc.

XML ≠ machine accessible meaning



But, to your machine, the tags still look like this....

The tag names carry no meaning.

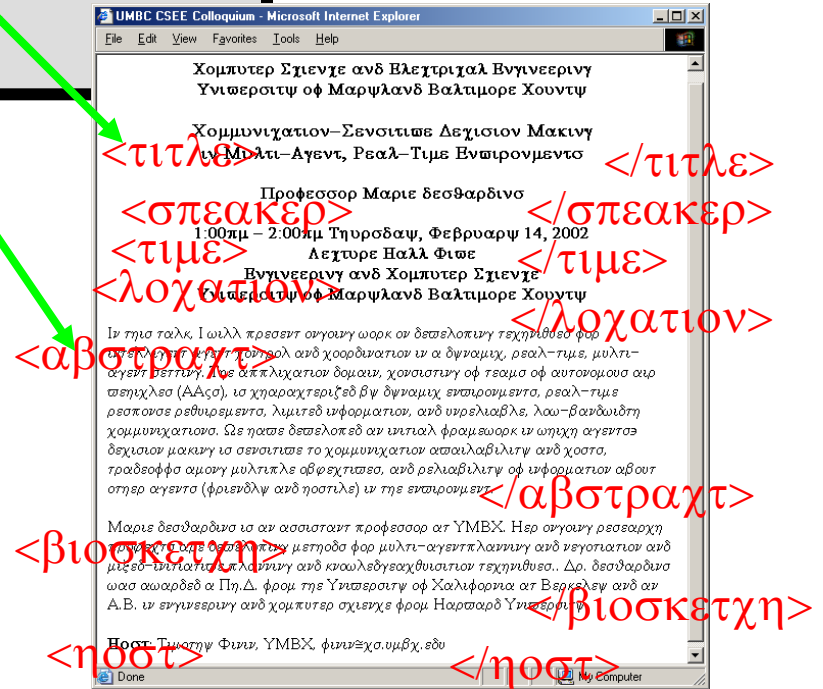
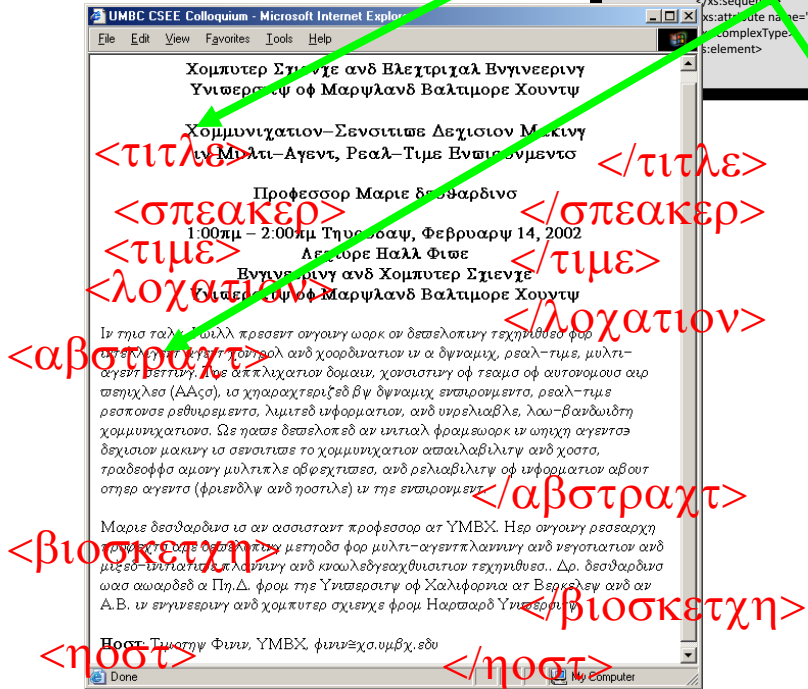
XML DTDs and Schemas have little or no semantics.

XML Schema helps

XML Schemas provide a simple mechanism to define shared vocabularies.

XML Schema file

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="book">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="title" type="xs:string"/>
        <xs:element name="author" type="xs:string"/>
        <xs:element name="character" minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:sequence>
    <xs:element name="name" type="xs:string"/>
    <xs:element name="friend-of" type="xs:string" minOccurs="0"
      maxOccurs="unbounded"/>
    <xs:element name="since" type="xs:date"/>
    <xs:element name="qualification" type="xs:string"/>
  </xs:sequence>
  <xs:complexType>
    <xs:element>
      <xs:sequence>
        <xs:attribute name="isbn" type="xs:string"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

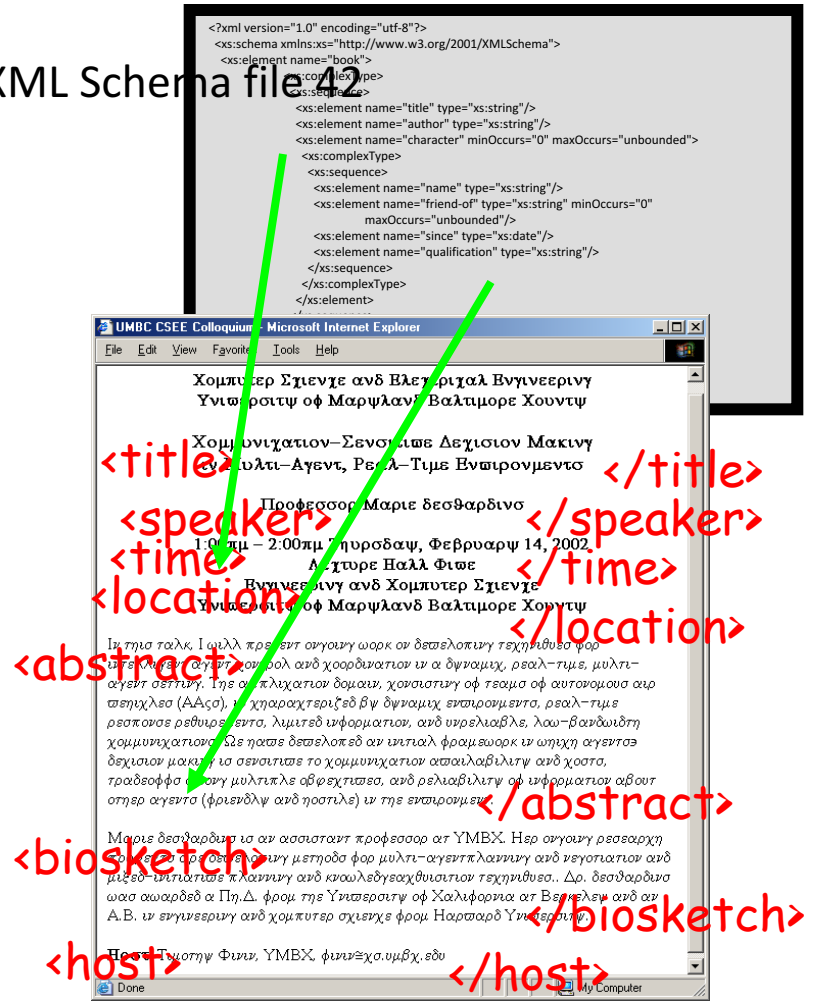
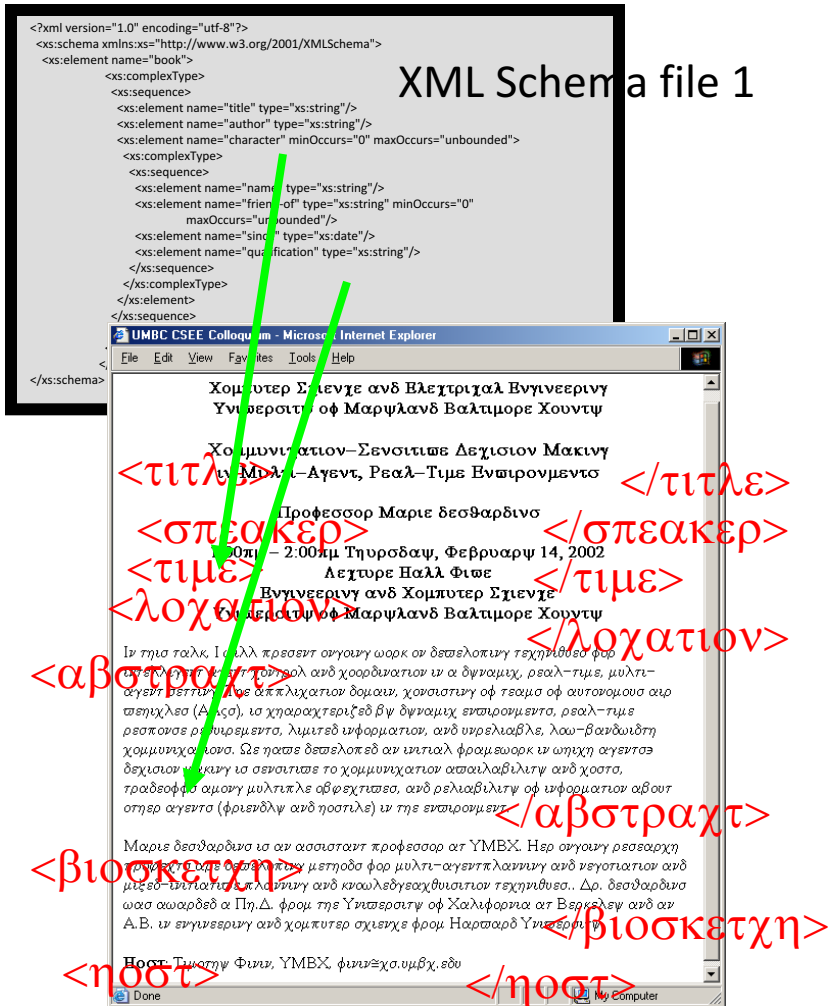


after Frank van Harmelen and Jim Hendler

But there are many schemas

XML Schema a file 1

XML Schema file 42

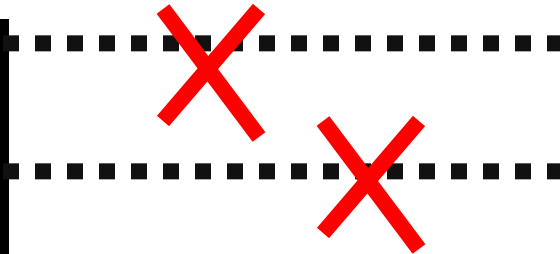


after Frank van Harmelen and Jim Hendler

There's no way to relate schema

XML Schema file 1

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="book">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="title" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="speaker" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="time" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="location" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="abstract" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="biosketch" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="host" type="xs:string" minOccurs="1" maxOccurs="1"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```



XML Schema file 42

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="book">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="title" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="speaker" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="time" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="location" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="abstract" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="biosketch" type="xs:string" minOccurs="1" maxOccurs="1"/>
        <xs:element name="host" type="xs:string" minOccurs="1" maxOccurs="1"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

<title>Χομπιτερ Στιενς ανδ Ηλεκτρικαλ Βηνιερριν
Υνιερσιτυ οφ Μαρψλανδ Βαλτιμορε Χουντψ
Χομπιναχτιον-Σενσιτιβε Δεχισιον Μακινγ
ανδ Μουλτι-Αγενη, Ρεαλ-Τιμε Βηνιερρινμεντο
Προφεσορ Μαριε δεσθαρινδο
1.00πμ - 2.00πμ Τηυροδαψ, Φεβρουαρψ 14, 2002
Λεχτωρε Χαλλ Φιβε
Βηνιερριν ανδ Χομπιτερ Στιενς
Υνιερσιτυ οφ Μαρψλανδ Βαλτιμορε Χουντψ
Ιν τησ ταλκ, Ιωιλλ πρεσεντ οηγουγ ωορκ ον δεσπελοπιγ τεχνηθσο φορ
μυλτι-αγενη τεχνηθσο ανδ χοορδινατιον ιν α δηναμικ, ρεαλ-τιμε, μυλτι-
αγενη δεστηγ, της αππλιχατιον δομου, χοουσιτυ οφ τσαμο οφ αυτανομοια αιρ
σπηχλεο (ΑΑςο), ιο χοραοχτεριζεθ βγ δηναμικ ενιερρινμεντο, ρεαλ-τιμε
ρεσποναο ρεθυερμεντο, λιμιτεδ ινφορματιον, ανδ υνιερλιαβλε, λαυ-βανδωιδη
χομπιναχτιον. Ωε ηαοοο δεσπελοπεδ αν ινιτιαλ φραμωορκ ιν ινιχη αγεντοο
δεχισιον μακινγ ιο σενσιτιβε το χομπιναχτιον απσιλαβιλιτψ ανδ χοοτο,
τραδεοφφα αμογ μυλτιπλεο οβφοχτιωο, ανδ ρελιαβιλιτψ οφ ινφορματιον αβοοτ
οτηερ αγεντο (φοιενδλψ ανδ ηοοτιλε) ιν της ενιερρινμεντ
Μαριε δεσθαρινδο ιο αν απσιταντ προφεσορ ατ ΥΜΒΧ. Ηερ οηγουγ ρεσοαρη
ατ τησ ταλκ, δεσπελοπιγ μεθροδ φορ μυλτι-αγενη τεχνηθσο ανδ νεγοτιατιον ανδ
μυεο-ινιτιαλ τεχνηθσο ανδ κνωλεδεγχοχθισιτυ ανδ τεχνηθσο. Δρ. δεσθαρινδο
ωοο αωαορδεο ατ Πη.Δ. φορ της Υνιερσιτυ οφ Χαλιφορνια ατ Βερκελεψ ανδ αν
Α.Β. ιν ενγνερριν ανδ χομπιτερ σχιενς φορ Ηαρσαορδ Υνιερσιτυ
Ηοοτ Τυοτηγ Φινι, ΥΜΒΧ, φιυνεχα.υμβχ.εδυ
Done My Computer

</title>
</speaker>
</time>
</location>
</abstract>
</biosketch>
</host>

Either manually or automatically.
XML Schema is weak on semantics.

An Ontology level is needed

XML
Ontology
256

imports

XML Ontology 1

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="book">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="title" type="xs:string"/>
        <xs:element name="author" type="xs:string"/>
        <xs:element name="character" minOccurs="0" maxOccurs="unbounded"/>
        <xs:complexType>
          <xs:sequence>
            <xs:element name="name" type="xs:string"/>
            <xs:element name="friend-of" type="xs:string" minOccurs="0"
              maxOccurs="unbounded"/>
            <xs:element name="since" type="xs:date"/>
            <xs:element name="qualification" type="xs:string"/>
          </xs:sequence>
        </xs:complexType>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:attribute name="isbn" type="xs:string"/>
</xs:schema>
```

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="book">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="title" type="xs:string"/>
        <xs:element name="author" type="xs:string"/>
        <xs:element name="character" minOccurs="0" maxOccurs="unbounded"/>
        <xs:complexType>
          <xs:sequence>
            <xs:element name="name" type="xs:string"/>
            <xs:element name="friend-of" type="xs:string" minOccurs="0"
              maxOccurs="unbounded"/>
            <xs:element name="since" type="xs:date"/>
            <xs:element name="qualification" type="xs:string"/>
          </xs:sequence>
        </xs:complexType>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:attribute name="isbn" type="xs:string"/>
</xs:schema>
```

Ontologies add

- Structure
- Constraints
- mappings

imports

XML Ontology 42

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="book">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="title" type="xs:string"/>
        <xs:element name="author" type="xs:string"/>
        <xs:element name="character" minOccurs="0" maxOccurs="unbounded"/>
        <xs:complexType>
          <xs:sequence>
            <xs:element name="name" type="xs:string"/>
            <xs:element name="friend-of" type="xs:string" minOccurs="0"
              maxOccurs="unbounded"/>
            <xs:element name="since" type="xs:date"/>
            <xs:element name="qualification" type="xs:string"/>
          </xs:sequence>
        </xs:complexType>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:attribute name="isbn" type="xs:string"/>
</xs:schema>
```

We need a way to define ontologies in XML

So we can relate them

So machines can understand (to some degree) their meaning

Semantic Web

Use Semantic Web Technology
to publish shared data &
knowledge

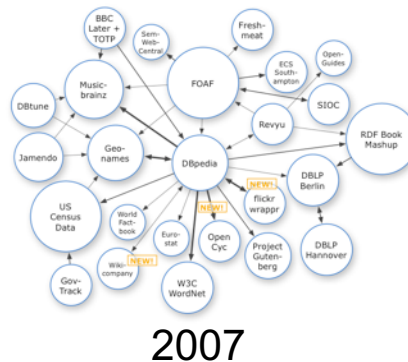
Semantic web technologies
allow machines to share
data and knowledge using
common web language and
protocols.

~ 1997

Semantic Web beginning

Semantic Web => Linked Open Data

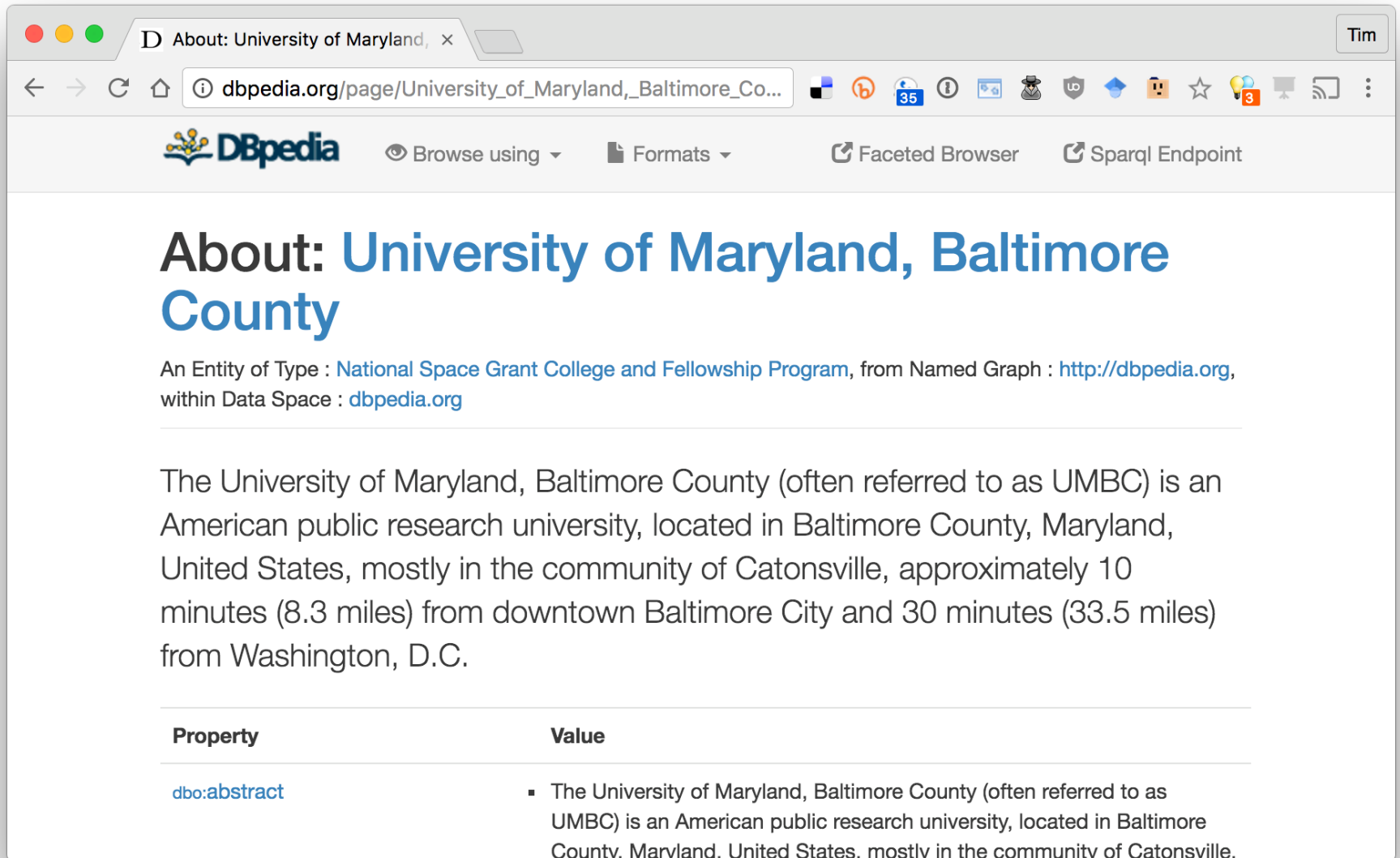
Use Semantic Web Technology
to publish shared data &
knowledge



Data is inter-
linked to support inte-
gration and fusion of knowledge

LOD beginning

The node in the center is DBpedia



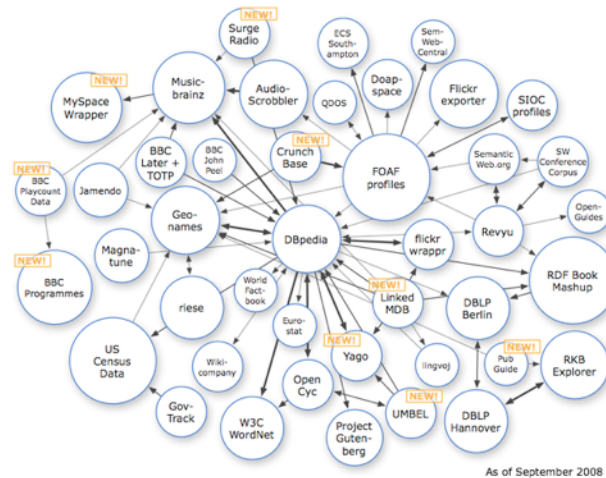
The screenshot shows a web browser window with the address bar displaying `dbpedia.org/page/University_of_Maryland,_Baltimore_Co...`. The page title is "About: University of Maryland, Baltimore County". Below the title, it states: "An Entity of Type : [National Space Grant College and Fellowship Program](#), from Named Graph : <http://dbpedia.org>, within Data Space : dbpedia.org". The main text describes the University of Maryland, Baltimore County (UMBC) as an American public research university located in Baltimore County, Maryland, United States, mostly in the community of Catonsville, approximately 10 minutes (8.3 miles) from downtown Baltimore City and 30 minutes (33.5 miles) from Washington, D.C. Below the text is a table with two columns: "Property" and "Value". The table contains one row with the property `dbo:abstract` and a value describing the university.

Property	Value
<code>dbo:abstract</code>	The University of Maryland, Baltimore County (often referred to as UMBC) is an American public research university, located in Baltimore County, Maryland, United States, mostly in the community of Catonsville,

http://dbpedia.org/page/University_of_Maryland,_Baltimore_County

Semantic Web => Linked Open Data

Use Semantic Web Technology
to publish shared data &
knowledge



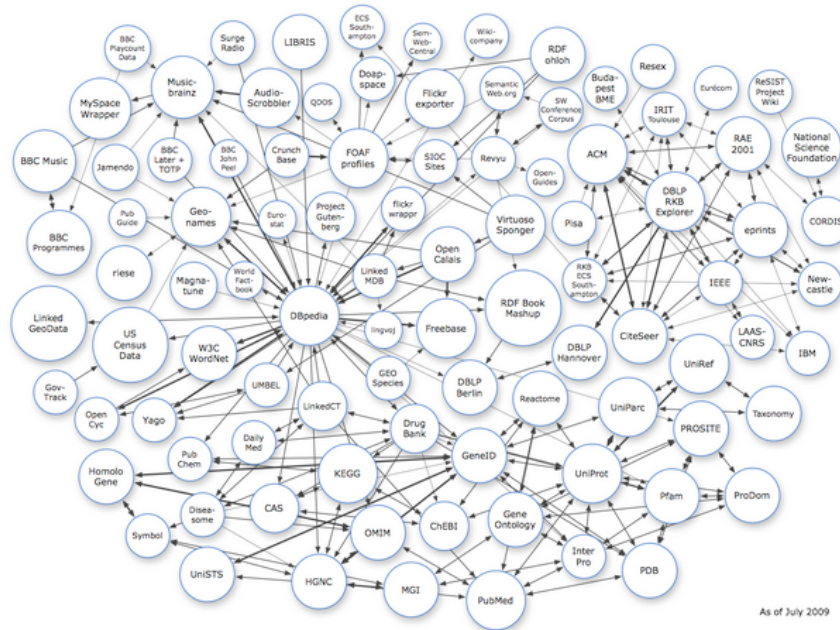
2008

Data is inter-
linked to support inte-
gration and fusion of knowledge

LOD growing

Semantic Web => Linked Open Data

Use Semantic Web Technology to publish shared data & knowledge



2009

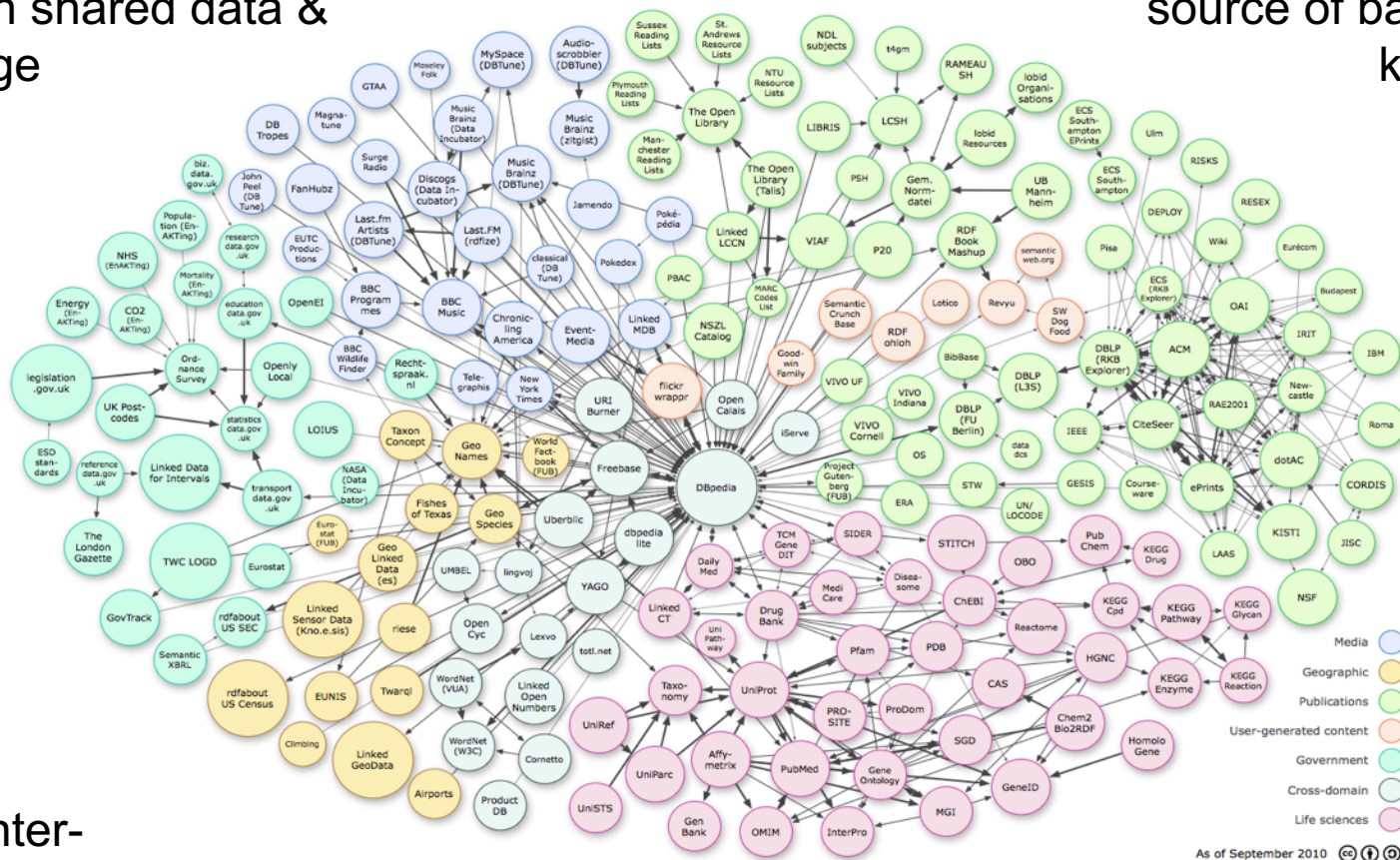
Data is inter-linked to support integration and fusion of knowledge

... and growing

Linked Open Data

Use Semantic Web Technology to publish shared data & knowledge

LOD is the new Cyc: a common source of background knowledge



Data is inter-linked to support integration and fusion of knowledge

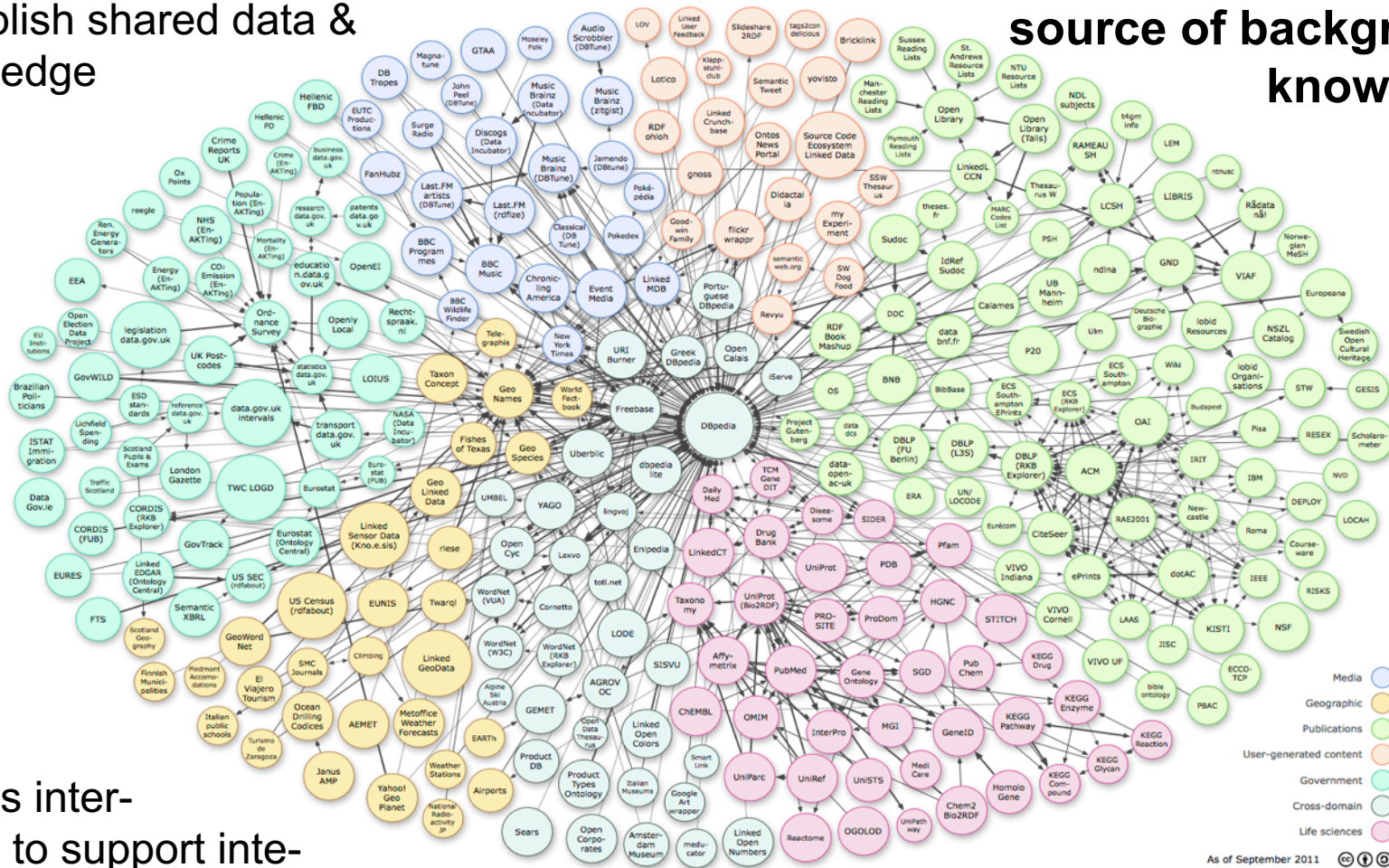
2010

...growing faster

Linked Open Data

Use Semantic Web Technology
to publish shared data &
knowledge

LOD is the new Cyc: a common
source of background
knowledge



Data is inter-
linked to support inte-
gration and fusion of knowledge

2011: 31B facts in 295 datasets interlinked by 504M assertions on ckan.net

Semantic Web: 1, 2, 3

Traditionally, all languages are divided into three parts:

1. **Syntax:** legal forms that make up the sentences in a language
2. **Semantics:** mapping of sentences to meaning (perhaps truth theoretic)
3. **Pragmatics:** everything else (how to do things with language, knowledge of world, etc.)

1: Syntax

- Use URIs* to denote classes, properties, objects, relations
 - http://live.dbpedia.org/resource/Alan_Turing
 - <http://schema.org/Person>
 - <http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
- Use strings for literals
- Use triples to make statements
 - dbpedia:Alan_Turing rdfs:type schema:Person .
 - “Alan Turing is a Person”

*URI = [Uniform Resource Identifier](#)

2: Semantics

- Semantics maps URIs to the things they denote in “the world”
- Some of this is in your mind or in how you write your program
- The meaning of some URIs allow automatic inference
 - **Parent** relation is **inverse** of the **child** relation
 - schema:parent owl:inverse schema:children

3: Pragmatics

- Semantics is more than just about truth (statements that assert things)
- We also have to account for commands, requests, questions, context, etc.
 - Some of this is handled by Web protocols (GET, POST)
 - Some by special SQ protocols (e.g., SPARQL for queries and updates)
 - Some by having reference KBs of the world (e.g., DBpedia) to help identify common entities

Where are we

- The W3C version of the open semantic web has been growing steadily
- The languages and standards are being used in government and industry
 - BBC uses RDF to make up much of its content online
 - Google and Facebook detect AND MAKE USE OF (some) RDF embedded in html pages
 - Google, Yahoo, Microsoft and Yandex formed Schema.org to develop useful vocabularies
 - Data.gov has many datasets in RDF

Wikipedia data
in RDF

DBpedia

<

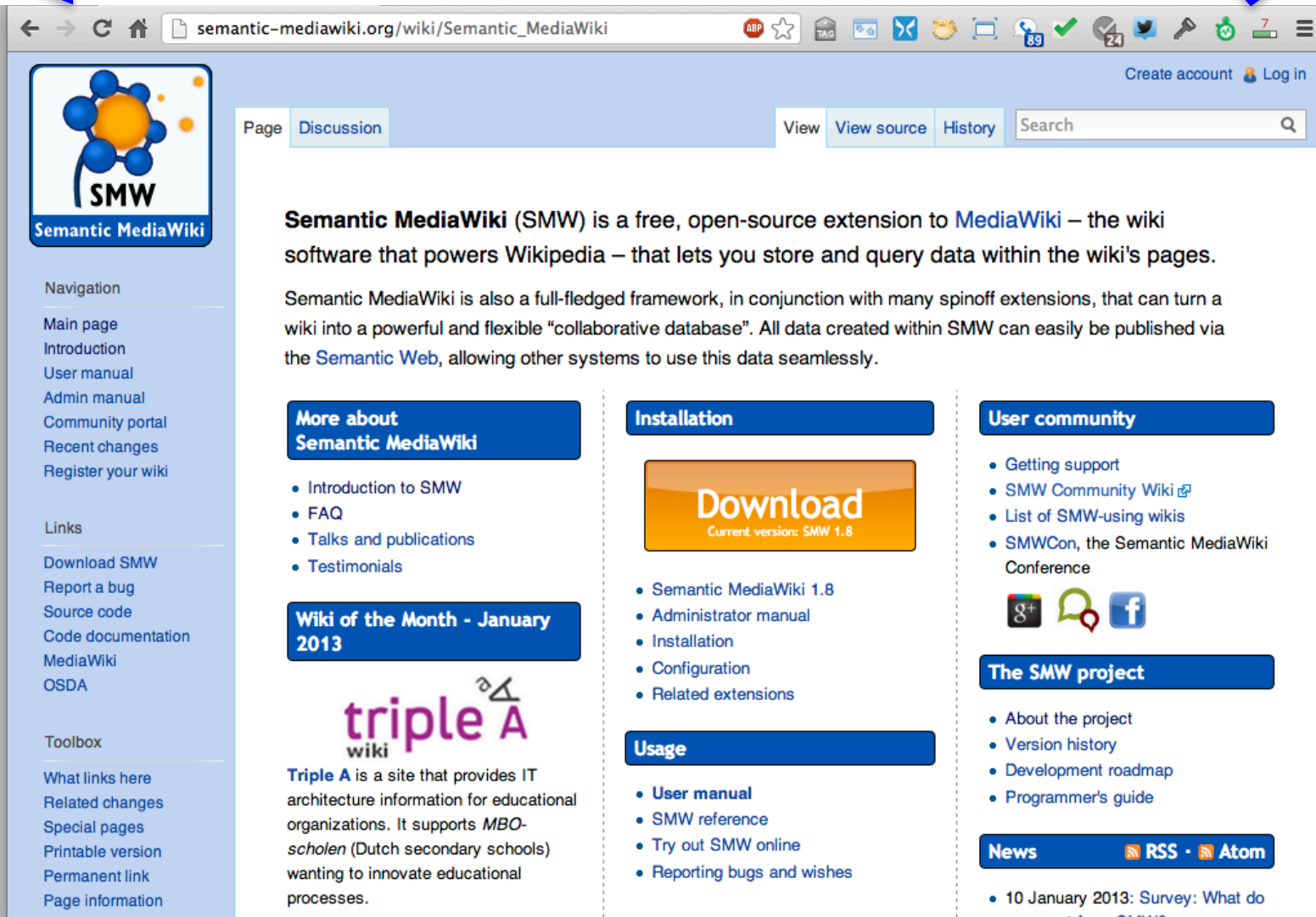
Wikidata

- [Wikidata](#) aims to create a free rdf-like KB about the world that can be read/edited by humans & machines
 - Wikimedia project started in April 2012 with external funding
- Wikidata clients use the repository, e.g., to populate Web pages or Wikipedia infoboxes
- Based on ideas from [Semantic MediaWiki](#) and [Freebase](#)

Open source
since 2005

Semantic Media Wiki

Store infobox
info in a KB



The screenshot shows the Semantic MediaWiki (SMW) homepage. The browser address bar displays `semantic-mediawiki.org/wiki/Semantic_MediaWiki`. The page features a blue header with navigation links like "Page", "Discussion", "View", "View source", and "History". A search bar is located on the right. The main content area is titled "Semantic MediaWiki (SMW) is a free, open-source extension to MediaWiki – the wiki software that powers Wikipedia – that lets you store and query data within the wiki's pages." Below this, a paragraph describes SMW as a full-fledged framework. The page is divided into three columns: "More about Semantic MediaWiki" (with links to Introduction, FAQ, Talks, and Testimonials), "Installation" (with a large "Download" button for version 1.8 and links to manuals and extensions), and "User community" (with links to support, wikis, and the conference). A "Wiki of the Month - January 2013" section highlights "triple A wiki". The right sidebar includes "The SMW project" (with links to project details, version history, and roadmap) and "News" (with RSS and Atom feeds).

semantic-mediawiki.org/wiki/Semantic_MediaWiki

Create account Log in

Page Discussion View View source History Search

Semantic MediaWiki (SMW) is a free, open-source extension to [MediaWiki](#) – the wiki software that powers Wikipedia – that lets you store and query data within the wiki's pages.

Semantic MediaWiki is also a full-fledged framework, in conjunction with many spinoff extensions, that can turn a wiki into a powerful and flexible "collaborative database". All data created within SMW can easily be published via the [Semantic Web](#), allowing other systems to use this data seamlessly.

More about Semantic MediaWiki

- Introduction to SMW
- FAQ
- Talks and publications
- Testimonials

Wiki of the Month - January 2013

triple A wiki

Triple A is a site that provides IT architecture information for educational organizations. It supports *MBO-scholen* (Dutch secondary schools) wanting to innovate educational processes.

Installation

Download
Current version: SMW 1.8

- Semantic MediaWiki 1.8
- Administrator manual
- Installation
- Configuration
- Related extensions

Usage

- User manual
- SMW reference
- Try out SMW online
- Reporting bugs and wishes

User community

- Getting support
- SMW Community Wiki
- List of SMW-using wikis
- SMWCon, the Semantic MediaWiki Conference

The SMW project

- About the project
- Version history
- Development roadmap
- Programmer's guide

News RSS Atom

- 10 January 2013: Survey: What do you think of SMW?

Freebase

Acquired by
Google in 2010

The screenshot shows the Freebase website interface for the topic 'Alan Turing'. The browser address bar displays 'www.freebase.com/view/en/alan_turing'. The top navigation bar includes 'Freebase', a search bar, and links for 'Data', 'Schema', 'Apps', 'Docs', 'finin', 'Settings', and 'Sign Out'. The main content area features a portrait of Alan Turing, a detailed biographical paragraph, and a list of properties such as 'Date of birth', 'Date of death', 'Profession', 'Country of nationality', and 'Also known as'. A sidebar on the left lists various categories like 'People', 'Literature Subject', and 'Computers'. On the right, there are sections for 'These people have edited this topic', 'Related Topics' (listing Edward Thomas Hall, Alan Turing, William Kingdon Clifford, and Ada Lovelace), and 'Alan Turing elsewhere on the web' (linking to the Official Website and Wikipedia). At the bottom, a 'People' section contains a 'Place of birth' field and a 'Quotes' section with two entries: 'Mathematical reasoning may be regarded...' and 'No, I'm not interested in developing a powerful brain...'.

www.freebase.com/view/en/alan_turing

Freebase Find topics... Data Schema Apps Docs finin Settings Sign Out

Alan Turing

Scroll to:

- People
- Literature Subject
- Influence Node
- Computers
- Name source
- Academic
- Chivalric Order Member
- Inventor
- Author
- Person Or Being In Fiction
- Organization member
- Film subject
- TV subject
- More...



Alan Mathison Turing, OBE, FRS (/ˈtjʊərɪ/ TEWR-ing; 23 June 1912 – 7 June 1954), was a British mathematician, logician, cryptanalyst, and computer scientist. He was highly influential in the development of computer science, giving a formalisation of the concepts of "algorithm" and "computation" with the Turing machine, which can be considered a model of a general purpose computer. Turing is widely considered to be the father of computer science... [More](#)

[Read article at Wikipedia](#)

Date of birth: Jun 23, 1912

Date of death: Jun 7, 1954 (age 41 years)

Profession: [Mathematician](#), [Philosopher](#), [Computer Scientist](#), [Logician](#)

Country of nationality: [United Kingdom](#)

Also known as: Alan Mathison Turing

These people have edited this topic:

 [Edit this topic](#)

Last edited Dec 12, 2012 [See all topic history »](#)

Related Topics

-  [Edward Thomas Hall](#)
-  [Alan Turing](#)
-  [William Kingdon Clifford](#)
-  [Ada Lovelace](#)

Alan Turing elsewhere on the web

- [★ Official Website](#)
- [Wikipedia](#)

People

Place of birth: [Maida Vale, United Kingdom](#)

Alan Turing Quotes

“ Mathematical reasoning may be regarded... ”

“ No, I'm not interested in developing a powerful brain... ”

“An entity graph of people, places and things, built by a community that loves open data”

Google Knowledge Graph

The screenshot shows the Google Knowledge Graph interface. At the top, the Google logo and "Inside Search" are visible. Below the navigation bar, a large network graph is displayed with various entities as nodes and their relationships as edges. A prominent blue circle contains a portrait of Leonardo da Vinci. Other nodes include a Canadian flag, a globe, and a portrait of a woman. To the right, a detailed card for Leonardo da Vinci is shown, featuring his portrait and biographical information. The card includes the text: "Leonardo di ser Piero da Vinci was an Italian Renaissance polymath: painter, sculptor, architect, musician, scientist, mathematician, engineer, inventor, anatomist, geologist, cartographer, botanist, and writer. Wikipedia". Below this, it lists his birth and death dates, burial place, parents, and a project. At the bottom, the text "The Knowledge Graph" is displayed, followed by "Learn more about one of the key breakthroughs behind the future of search...". To the right, the text "See it in action" is displayed, followed by "Discover answers to questions you thought to ask, and explore collected".

Google Inside Search

Home Tips & Tricks **Features** Search Stories Playground Blog Help

The Knowledge Graph

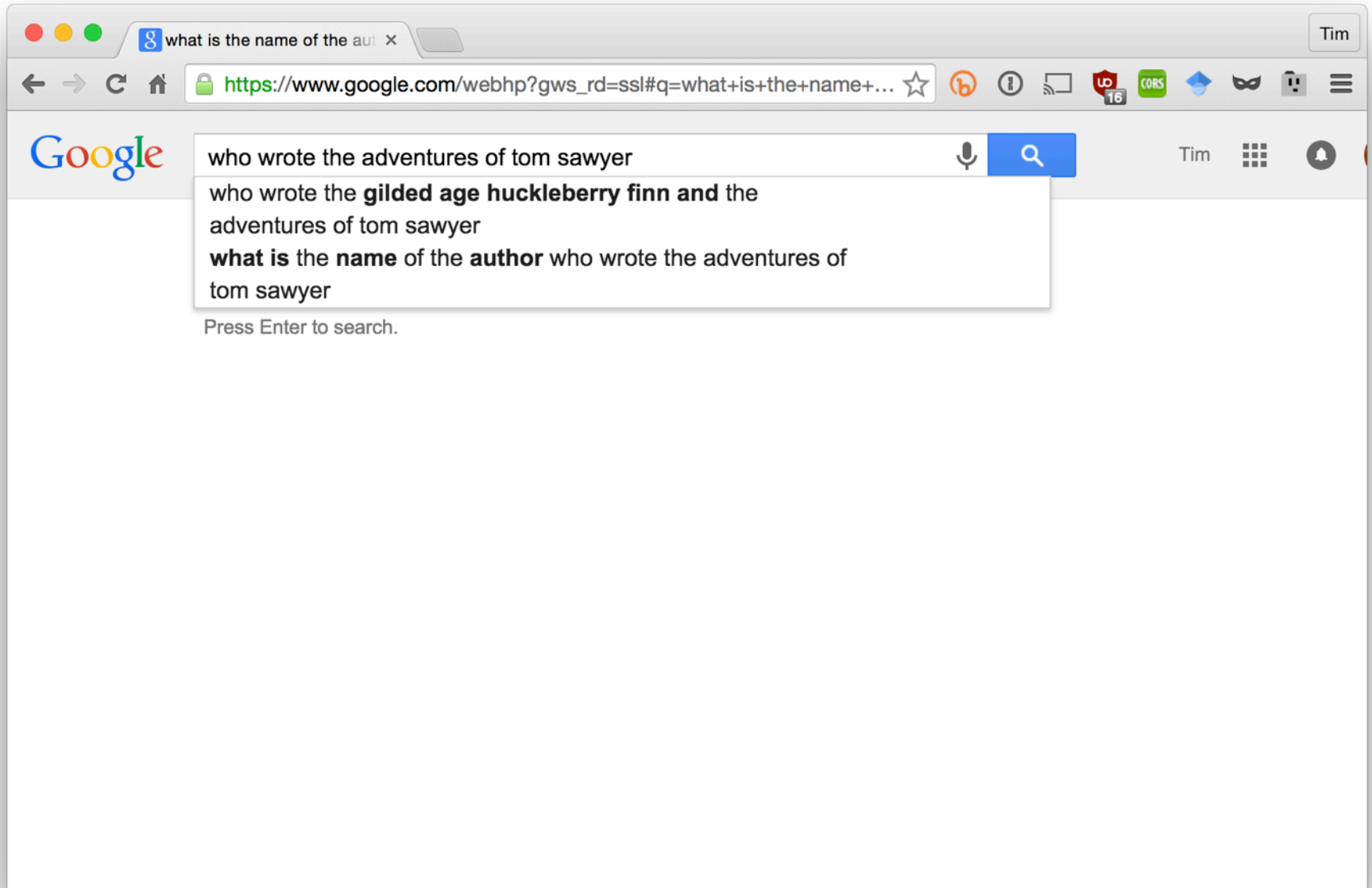
Learn more about one of the key breakthroughs behind the future of search...

See it in action

Discover answers to questions you thought to ask, and explore collected

Google's slogan for the knowledge graph: "things, not strings"

Who wrote Tom Sawyer?



Who wrote Tom Sawyer?

who wrote the adventures of tom sawyer

Google

who wrote the adventures of tom sawyer

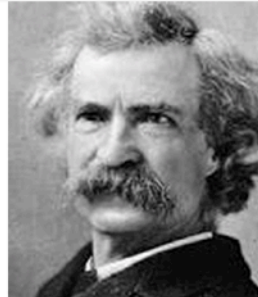
Web Shopping Videos Images News More Search tools

About 221,000 results (0.72 seconds)

Mark Twain

The Adventures of Tom Sawyer, Author

Books and overview



Feedback

[The Adventures of Tom Sawyer - Wikipedia, the free ...](https://en.wikipedia.org/wiki/The_Adventures_of_Tom_Sawyer)
https://en.wikipedia.org/wiki/The_Adventures_of_Tom_Sawyer - Wikipedia

The Adventures of Tom Sawyer by Mark Twain is an 1876 novel about a young boy growing up along the Mississippi River. The story is set in the fictional town of St. Petersburg, inspired by Hannibal, Missouri, where Twain lived.

[List of Tom Sawyer characters](#) - [Tom Sawyer Abroad](#) - [Hannibal, Missouri](#) - [2000 film](#)

Who wrote Tom Sawyer?

who wrote the adventures

https://www.google.com/webhp?gws_rd=ssl#q=who+wrote+the+adventures+of+tom+sawyer

Google

who wrote the adventures of tom sawyer

Tim

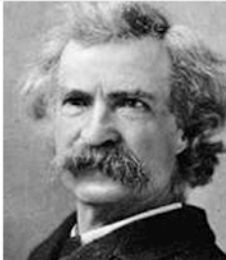
Tim

Web Shopping Videos Images News More Search tools

About 221,000 results (0.50 seconds)

Mark Twain

The Adventures of Tom Sawyer, Author



Samuel Langhorne Clemens, better known by his pen name Mark Twain, was an American author and humorist. He wrote The Adventures of Tom Sawyer and its sequel, Adventures of Huckleberry Finn, the latter often called "The Great American Novel".
[Wikipedia](#)

Born: November 30, 1835, [Florida, MO](#)

Died: April 21, 1910, [Redding, CT](#)

Full name: Samuel Langhorne Clemens

Spouse: [Olivia Langdon Clemens](#) (m. 1870–1904)

Buried: April 24, 1910, [Woodlawn Cemetery, Elmira, NY](#)

 [Get updates about Mark Twain](#)

Apple Pie by Grandma Ople

★★★★★

9K made it | 6969 reviews

 26

Recipe by: MOSHASMAMA

"This was my grandmother's apple pie recipe. I have never seen another one quite like it. It will always be my favorite and has won me several first place prizes in local competitions. I hope it becomes one of your favorites as well!"



Featured in Allrecipes Magazine

Save

I Made It

Rate it

Share

Print

Ingredients

1 h 30 m ⌚ 8 servings 🍽️ 512 cals 📊

+

1 recipe pastry for a 9 inch double crust pie

+

1/2 cup white sugar

+

1/2 cup unsalted butter

Domino Pure Cane Granulated Sugar



On Sale

On

⚙️

What's on sale near you.

>

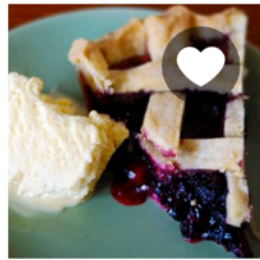


Grandma Ople's Apple Pie

★★★★★ 1930

Related

Recipes Videos Categories Articles



Blueberry Pie

★★★★★ 1K

Recipe by ASHESP

👤 3 ❤️ 0 🔔 1

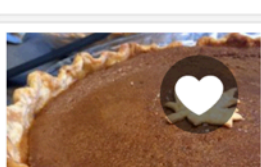


All-Day Apple Butter

★★★★★ 883

Recipe by Terri





Apple Pie by Grandma Ople

allrecipes!

BROWSE

Find a recipe

Home > Recipes > Desserts > Pies > Fruit Pies

Apple Pie by Grandma Ople

★★★★★

9K made it | 6969 reviews

Recipe by: MOSHASHAMA

"This was my grandmother's apple pie recipe. I have never seen another one quite like it. It will always be my favorite and has won me several first place prizes in local competitions. I hope it becomes one of your favorites as well!"

Featured in Allrecipes Magazine

Save

I Made It

Rate it

Ingredients

+ 1 recipe pastry for a 9 inch double crust pie

+ 1/2 cup white sugar

+ 1/2 cup unsalted butter

Domino Pure Cane Granulated Sugar

On Sale

What's on sale near you.

page dataon-line toolsoptions

META SEO Inspector v2.0.8

COMMON

WARNING missing keywords tag

head title : Apple Pie by Grandma Ople Recipe - Allrecipes.com (49 characters)

description : A unique and popular recipe. Sliced apples under a lattice crust get bathed with a sweet buttery sauce before baking. (117 characters)

robots : noodp,noydir

OPENGGRAPH (FaceBook)

og:title : Apple Pie by Grandma Ople Recipe

og:site_name : Allrecipes

og:description : A unique and popular recipe. Sliced apples under a lattice crust get bathed with a sweet buttery sauce before baking.

og:url : http://allrecipes.com/recipe/12682/apple-pie-by-grandma-ople/

og:type : article

og:image : http://images.media-allrecipes.com/userphotos/720x405/736203.jpg

og:rating : 4.77072191238403

og:rating_scale : 5

SCHEMA.ORG (GooglePlus rich snippets)

itemprop:url (6) itemprop:mainEntityOfPage (1) itemprop:title (5) itemprop:image (2) itemprop:video (1) itemtype:http://schema.org/VideoObject (1) itemprop:thumbnailUrl (1) itemprop:embedUrl (1) itemprop:name (2) itemprop:description (2) itemprop:interactionCount (1) itemprop:uploadDate (1) itemprop:aggregateRating (1) itemtype:http://schema.org/AggregateRating (1) itemprop:ratingValue (12) itemprop:reviewCount (1) itemprop:author (12) itemprop:recipeYield (1) itemprop:nutrition (2) itemtype:http://schema.org/NutritionInformation (2) itemprop:calories (1) itemprop:fatContent (1) itemprop:carbohydrateContent (1) itemprop:proteinContent (1) itemprop:cholesterolContent (1) itemprop:sodiumContent (1) itemprop:ingredients (7) itemprop:prepTime (1) itemprop:cookTime (1) itemprop:totalTime (1) itemprop:recipeInstructions (1) itemprop:review (11) itemtype:http://schema.org/Review (11) itemprop:itemReviewed (11) itemprop:reviewRating (11) itemtype:http://schema.org/Rating (11) itemprop:dateCreated (11) itemprop:reviewBody (11)

OTHER META DATA

viewport : width=device-width, initial-scale=1.0

fb:app_id : 66102450266

msapplication-tilecolor : #ffffff

LINK

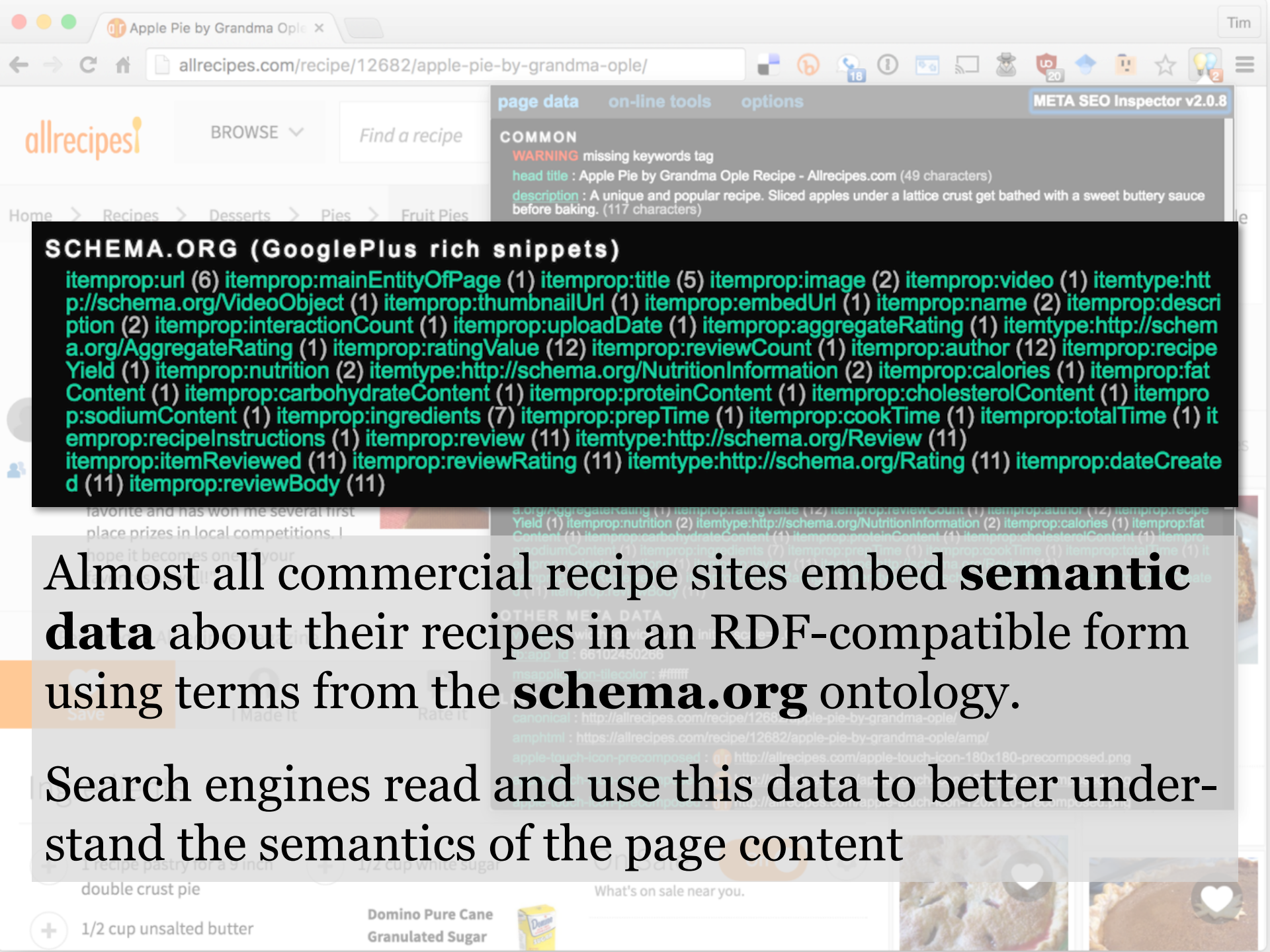
canonical : http://allrecipes.com/recipe/12682/apple-pie-by-grandma-ople/

amphtml : https://allrecipes.com/recipe/12682/apple-pie-by-grandma-ople/amp/

apple-touch-icon-precomposed : http://allrecipes.com/apple-touch-icon-180x180-precomposed.png

apple-touch-icon-precomposed : http://allrecipes.com/apple-touch-icon-152x152-precomposed.png

apple-touch-icon-precomposed : http://allrecipes.com/apple-touch-icon-120x120-precomposed.png



SCHEMA.ORG (GooglePlus rich snippets)

itemprop:url (6) itemprop:mainEntityOfPage (1) itemprop:title (5) itemprop:image (2) itemprop:video (1) itemtype:http://schema.org/VideoObject (1) itemprop:thumbnailUrl (1) itemprop:embedUrl (1) itemprop:name (2) itemprop:description (2) itemprop:interactionCount (1) itemprop:uploadDate (1) itemprop:aggregateRating (1) itemtype:http://schema.org/AggregateRating (1) itemprop:ratingValue (12) itemprop:reviewCount (1) itemprop:author (12) itemprop:recipeYield (1) itemprop:nutrition (2) itemtype:http://schema.org/NutritionInformation (2) itemprop:calories (1) itemprop:fatContent (1) itemprop:carbohydrateContent (1) itemprop:proteinContent (1) itemprop:cholesterolContent (1) itemprop:sodiumContent (1) itemprop:ingredients (7) itemprop:prepTime (1) itemprop:cookTime (1) itemprop:totalTime (1) itemprop:recipeInstructions (1) itemprop:review (11) itemtype:http://schema.org/Review (11) itemprop:itemReviewed (11) itemprop:reviewRating (11) itemtype:http://schema.org/Rating (11) itemprop:dateCreated (11) itemprop:reviewBody (11)

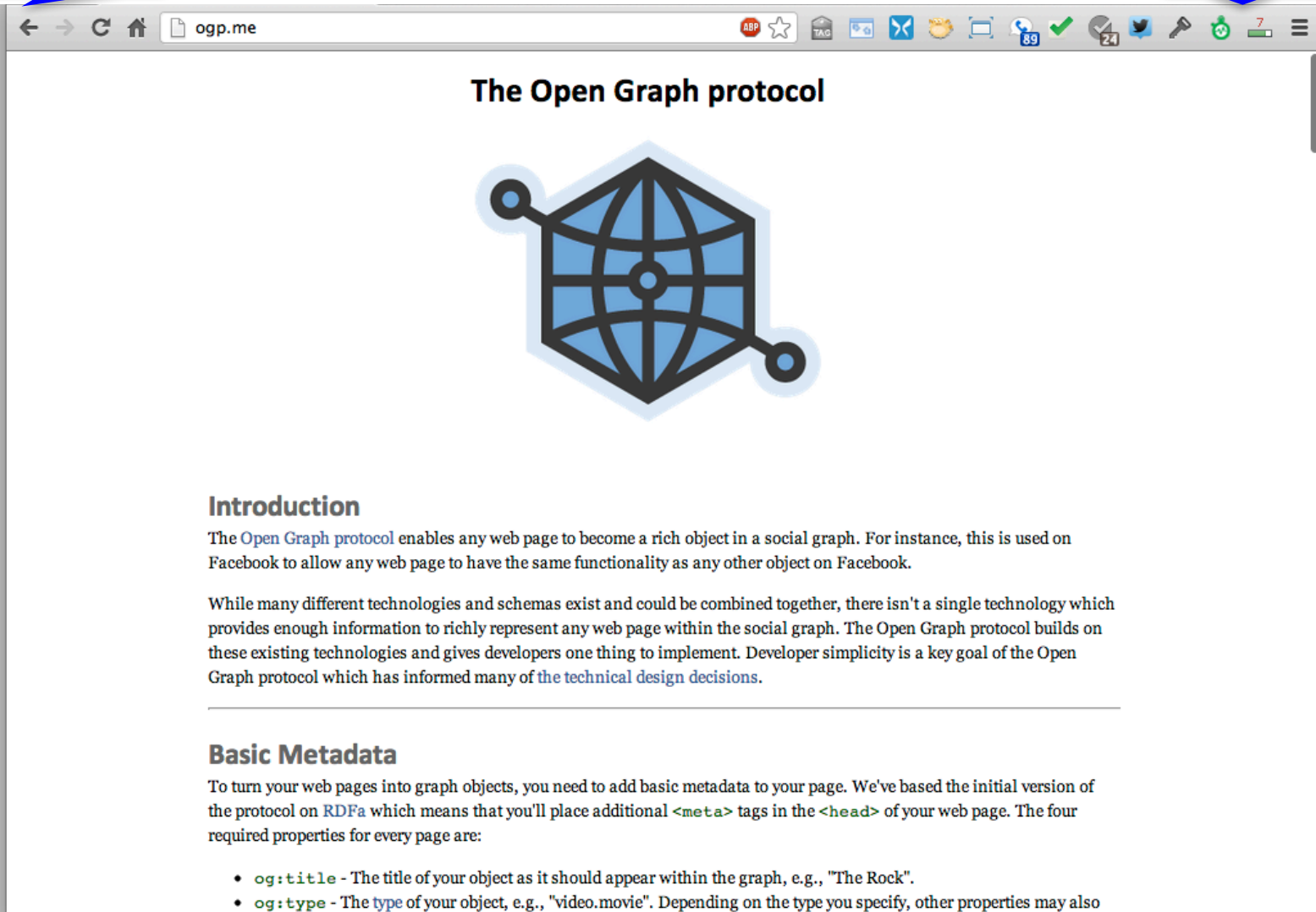
Almost all commercial recipe sites embed **semantic data** about their recipes in an RDF-compatible form using terms from the **schema.org** ontology.

Search engines read and use this data to better understand the semantics of the page content

Annotate your web
pages in RDFa

Facebook Open Graph

=> object in the FB
graph



The screenshot shows a web browser window with the address bar displaying 'ogp.me'. The page content includes a title 'The Open Graph protocol', a logo of a blue hexagon with a globe inside, and two sections: 'Introduction' and 'Basic Metadata'. The 'Introduction' section explains that the Open Graph protocol enables any web page to become a rich object in a social graph, used by Facebook. The 'Basic Metadata' section explains that to turn web pages into graph objects, basic metadata must be added to the page, specifically mentioning RDFa and the required properties for every page.

The Open Graph protocol



Introduction

The [Open Graph](#) protocol enables any web page to become a rich object in a social graph. For instance, this is used on Facebook to allow any web page to have the same functionality as any other object on Facebook.

While many different technologies and schemas exist and could be combined together, there isn't a single technology which provides enough information to richly represent any web page within the social graph. The Open Graph protocol builds on these existing technologies and gives developers one thing to implement. Developer simplicity is a key goal of the Open Graph protocol which has informed many of [the technical design decisions](#).

Basic Metadata

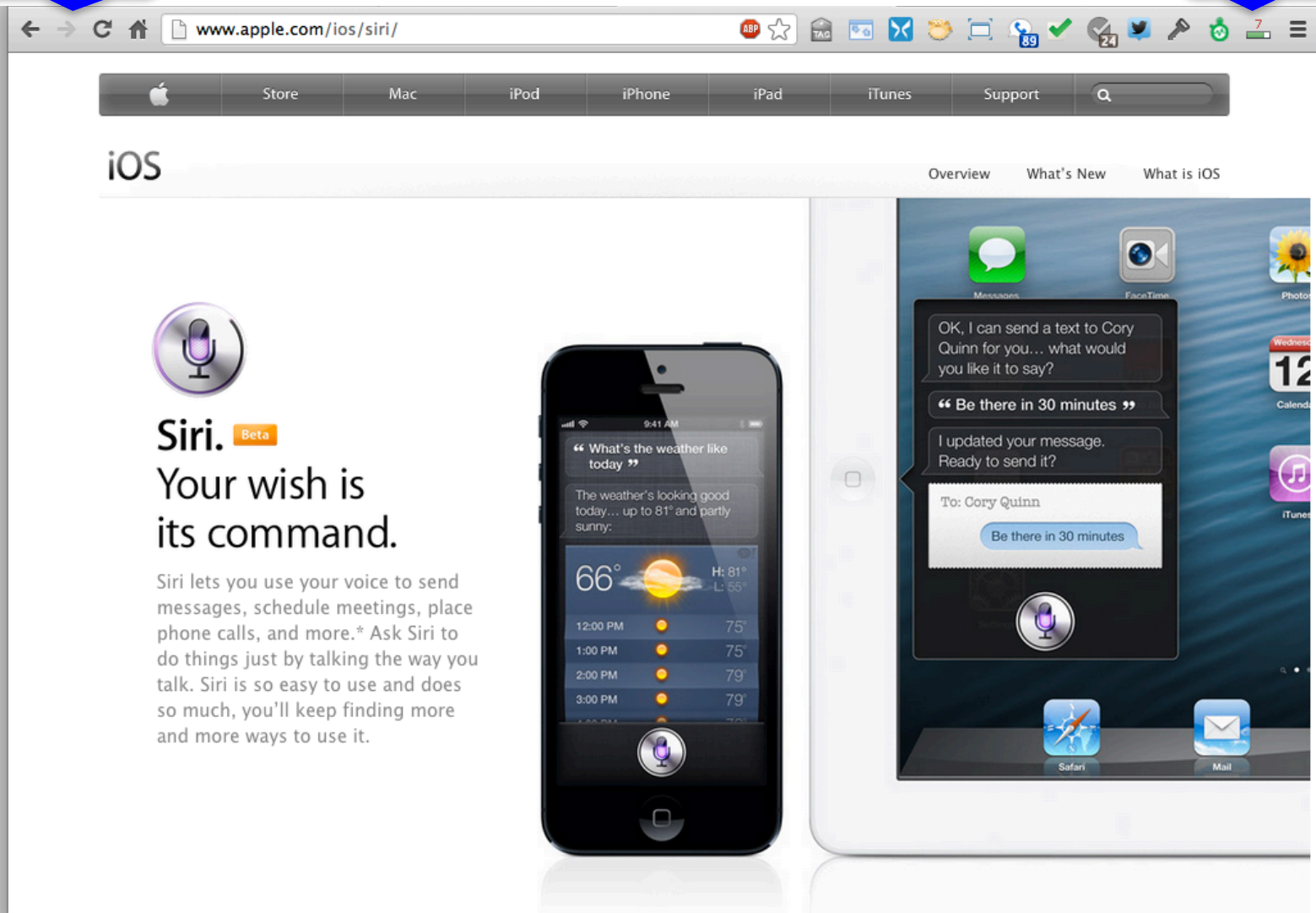
To turn your web pages into graph objects, you need to add basic metadata to your page. We've based the initial version of the protocol on [RDFa](#) which means that you'll place additional `<meta>` tags in the `<head>` of your web page. The four required properties for every page are:

- `og:title` - The title of your object as it should appear within the graph, e.g., "The Rock".
- `og:type` - The [type](#) of your object, e.g., "video.movie". Depending on the type you specify, other properties may also

speech => text =>
entities => task

Apple's SIRI

SIRI engineers
from AI/SW
community



SIRI needs lots of semantic data about entities in the world

IBM's Watson

The screenshot shows the IBM Watson website with a browser address bar at www-03.ibm.com/innovation/us/watson/. The page features a dark navigation bar with the IBM logo and links to Industries & solutions, Services, Products, Support & downloads, and My IBM. A search bar is also present. The main content area has a large heading "IBM Watson: Ushering in a new era of computing" and a subheading "What's next for Watson?" with a call to action "We want to hear how YOU would put Watson to work. Join the discussion" and a link "Learn more". To the right is a large graphic of a globe with blue and yellow lines representing data connections. Below the heading is a horizontal menu with tabs: Watson, Putting Watson to work, Science behind Watson, Getting ready for Watson, and News/events. The "Putting Watson to work" tab is active, showing a section with a globe graphic and the text "Cognitive systems like Watson may transform how organizations think, act, and operate in the future. Learning through interactions, they deliver evidence based responses driving better outcomes." Below this is a link "Watson goes to work (1.53MB)". To the right is a section "Contact IBM about Watson" with links "Email IBM" and "Or call us at: 1-800-966-9875 Priority code: 109HF03W". Below that is a section "Follow IBM Watson" with a YouTube icon. At the bottom, there is a section "Recent news" with links "IBM hopes its Watson will become doctor's sidekick", "IBM Exploring Ways to Use, Sell Watson Cloud Services", and "More Watson news". On the left side of the bottom section, there is a graphic of five blue human figures and a large blue and green arrow pointing right, with the text "Take the next step Is your business ready for Watson? Discover how to prepare your".

IBM Watson: Ushering in a new era of computing

What's next for Watson?
We want to hear how YOU would put Watson to work. Join the discussion
[Learn more](#)

Watson Putting Watson to work Science behind Watson Getting ready for Watson News/events

Cognitive systems like Watson may transform how organizations think, act, and operate in the future. Learning through interactions, they deliver evidence based responses driving better outcomes.

Watson goes to work (1.53MB)

Contact IBM about Watson
[Email IBM](#)
Or call us at: 1-800-966-9875
Priority code: 109HF03W

Follow IBM Watson

Recent news
[IBM hopes its Watson will become doctor's sidekick](#)
[IBM Exploring Ways to Use, Sell Watson Cloud Services](#)
[More Watson news](#)

Putting Watson to work
Data is growing at extraordinary rates - 800

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IBM used Semantic Web technology and data in Watson, see <http://bit.ly/X44aIE>

A collection of
useful ontologies

Schema.org

Embed in HTML using RDFa to
make machine understand-
able statements

The screenshot shows a web browser window with the address bar displaying 'schema.org/Person'. The page has a red header with the 'schema.org' logo on the left and a search bar on the right. Below the header is a navigation bar with links for 'Home', 'Schemas', and 'Documentation'. The main content area is titled 'Thing > Person' and includes a description: 'A person (alive, dead, undead, or fictional)'. Below this is a table listing properties for 'Thing' and 'Person'.

Property	Expected Type	Description
Properties from <u>Thing</u>		
<u>additionalType</u>	URL	An additional type for the item, typically used for adding more specific types from external vocabularies in microdata syntax. This is a relationship between something and a class that the thing is in. In RDFa syntax, it is better to use the native RDFa syntax – the 'typeof' attribute – for multiple types. Schema.org tools may have only weaker understanding of extra types, in particular those defined externally.
<u>alternateName</u>	Text	An alias for the item.
<u>description</u>	Text	A short description of the item.
<u>image</u>	URL	URL of an image of the item.
<u>name</u>	Text	The name of the item.
<u>sameAs</u>	URL	URL of a reference Web page that unambiguously indicates the item's identity. E.g. the URL of the item's Wikipedia page, Freebase page, or official website.
<u>url</u>	URL	URL of the item.
Properties from <u>Person</u>		
<u>additionalName</u>	Text	An additional name for a Person, can be used for a middle name.
<u>address</u>	<u>PostalAddress</u>	Physical address of the item.
<u>affiliation</u>	<u>Organization</u>	An organization that this person is affiliated with. For example, a school/university, a club, or a team.
<u>alumniOf</u>	<u>EducationalOrganization</u>	An educational organizations that the person is an alumni of.

Summary

- The Web has made us smarter by sharing information and knowledge as text, audio and images
- Machines should also be able to use the Web to publish & retrieve information & knowledge
- Human forms of knowledge are hard for machines to understand and generate
- The Semantic Web is a collection of languages, ontologies, software tools, services and KBs that are designed to support machines